ANÁLISIS DE LOS PATRONES DE MOVIMIENTO E INTENSIDAD DEL EJERCICIO EN FÚTBOL PROFESIONAL, EMPLEANDO SISTEMAS GPS Y LA RESPUESTA DE LA FRECUENCIA CARDIACA DURANTE PARTIDOS OFICIALES

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El doctorando D. Ignacio Torreño Jarabo y los directores de la tesis, Dr. D. Diego Munguía Izquierdo y Dr. D. Luis Jesús Suárez Moreno-Arrones, garantizamos al firmar esta tesis doctoral que el trabajo ha sido realizado por el doctorando, bajo la dirección de los directores de la tesis. Hasta dónde nuestro conocimiento alcanza en la realización del trabajo, se han respetado los derechos de otros autores al ser citados cuando se han utilizado sus resultados o publicaciones.

En Sevilla a 24 de Abril de 2017

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Doctorando:
Fdo.:

D. Ignacio Torreño Jarabo

“Cada día sabemos más y entendemos menos”

ALBERT EINSTEIN

“Hoy quiero dar gracias a la vida por lo que soy y por lo que no soy. Por lo que tengo y por lo que no tengo. Por haber nacido donde he nacido. Por tener la familia que tengo. Por tener los amigos que tengo. Por todo lo que aprendo y por todo lo que no entiendo, porque me hace seguir buscando. Por sentir, por recordar, por olvidar, por amar, por ser amado. Por hacerme reír, por hacerme llorar, por estar vivo.”

VICTORIA MARTÍNEZ LOJENDIO

Para ti Ana. Para ti Iago. Os quiero

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A todos los compañeros que han participado en los estudios de investigación presentados en esta tesis y han contribuido a mi proceso de aprendizaje, en especial el Dr. José Carlos Barbero, que me inició en el conocimiento de la tecnología GPS.

A todos los clubs de fútbol profesional donde he trabajado, y que me dieron la oportunidad de desarrollarme a todos los niveles, viviendo infinidad de experiencias. Y sobre todo a los jugadores que colaboraron activamente en el desarrollo de este proyecto con su participación en las investigaciones. Cada día aprendo de vosotros.

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ABREVIATURAS

(ABBREVIATIONS)

ABREVIATURAS (ABBREVIATIONS)

ANOVA	Analysis of variance
A League	Australian League
Acc	Accelerations
CB	Center back
CI	Confidence intervals
CV	Coefficient of variation
D	Distance
Eff_{index}	Index of performance efficiency
ES	Effect size
FC	Frecuencia cardiaca
FB	Fullback
FIFA	Federation International of Football Association
GPS	Global positioning system
HDOP	The horizontal dilution of position
HR	Heart rate
HR_{max}	Maximal heart rate
Hz	Hertz
JCR	Journal citations reports
Km/h	Kilometres per hour
MD	Midfielder
m	Meters
min	Minutes

$m.min^{-1}$	Meters per minute
m/s/s	Meters per second squared
$m.s^{-2}$	Meters per second squared
RSS	Repeated-sprint sequence
RTD	Relative total distance
s	second
S	Striker
SD	Standard deviations
SPSS	Social sciences package
TD	Total distance
TEE	Typical error of the estimate
UEFA	Union of European Football Associations
wk	Week
W-MD	Wide midfielder
2^{nd} S	Second striker
#	Number

PUBLICACIONES

(PUBLICATIONS)

PUBLICACIONES (PUBLICATIONS)

La presente memoria de Tesis Doctoral está compuesta por los siguientes artículos científicos:

I. Suarez-Arrones L, Torreno N, Requena B, et al. Match-play activity profile in professional soccer players during official games and the relationship between external and internal load. J Sports Med Phys Fitness. 2015 Dec; 55 (12):1417-1422.

El objetivo del presente estudio fue analizar por primera vez los patrones de movimiento e intensidad del ejercicio en jugadores de fútbol profesional durante partidos oficiales, mediante tecnología de posicionamiento global (GPS) y la respuesta de la frecuencia cardiaca (FC), cuantificando así la dosis-respuesta del estímulo de competición, carga externa y carga interna.

Los principales hallazgos del estudio reflejaron que la posición específica de juego influyó significativamente en la distancia cubierta, en la relación trabajo-descanso, en el rendimiento en sprint y en la frecuencia cardiaca media de los jugadores. La relación entre la carga externa e interna valorada en las diferentes posiciones específicas de juego, manifestó que aquellos jugadores con un menor rendimiento de carrera durante el partido, reflejaron peores valores en el índice de eficiencia (Eff_{index}). El presente trabajo analizó las demandas específicas durante partidos oficiales en jugadores profesionales de fútbol, empleando por primera vez dispositivos GPS. En base a esto, esta información podrá emplearse para desarrollar tareas de entrenamiento específicas por posición, basadas en un similar modelo de juego. La relación trabajo-descanso mostrada durante la competición, también podrá ayudar a los entrenadores a planificar protocolos de entrenamiento a través de ejercicios intermitentes específicos por posiciones.

II. Torreño N, Munguía-Izquierdo D, Coutts AJ, Sáez de Villarreal E, Asian-Clemente J, Suarez-Arrones L. Relationship Between External and Internal Load of Professional Soccer Players During Full-Matches in Official Games Using GPS and Heart Rate Technology. Int J Sports Physiol Perform. 2016 Oct; 11 (7): 940-946

El objetivo del estudio fue cuantificar por primera vez la carga interna y externa en jugadores élite de fútbol profesional, durante partidos oficiales completos, usando tecnología GPS y la respuesta de la frecuencia cardiaca. Los principales hallazgos del presente estudio, mostraron que para todas las posiciones de juego existió una reducción en la distancia recorrida durante la segunda mitad en comparación con la primera, y que durante los primeros 15 minutos de juego se recorrió una mayor distancia total en comparación con el resto de períodos del partido. Solamente los puestos específicos de segundo delantero ($2^{nd}S$) y delantero (S) manifestaron una frecuencia cardiaca media menor durante la segunda mitad (se mantuvo sin cambios en el resto), mientras que el Effindex se redujo sustancialmente en casi todas las posiciones de juego durante la segunda mitad. La posición específica de juego afectó a la distancia total cubierta (TD), a la distancia recorrida a diferentes velocidades y a las relaciones entre carga externa e interna, reflejando nuestros resultados, que aquellos jugadores con un mayor perfil de actividad locomotora en competición manifestaron valores más elevados de Eff_{index}.

III. Al Haddad H, Méndez-Villanueva A, Torreño N, Munguía- Izquierdo D, Suárez-Arrones L. Variability of GPS-derived running performance during official matches in 15 elite professional soccer players. J Sports Medicine and Physical Fitness. February 2017 (under review)

El presente trabajo analizó por primera vez en fútbol profesional, durante partidos oficiales, la variación en los patrones de movimiento partido a partido a lo largo de dos temporadas consecutivas, empleando tecnología GPS.

Nuestros resultados mostraron que el coeficiente de variación (CV) osciló partido a partido entre el 5.3% y el 70% en función de las diferentes variables locomotoras. La magnitud de este CV se incrementa a medida que aumenta la intensidad de carrera y/o aceleración, siendo también afectado de manera diferente según la posición específica de juego. Esta información sobre la variabilidad partido a partido empleando tecnología GPS, deberá tenerse en cuenta cuando se utilicen estas variables tanto para prescribir entrenamientos basados en las demandas de competición, como para monitorizar carga o intensidad del entrenamiento.

RESUMEN

(SUMMARY)

RESUMEN (SUMMARY)

The present document of International Doctoral Thesis represents a novelty and a big step in sport science and soccer. A path full of restlessness, in which an investigation has been developed clearly linked to the world of professional soccer in official matches, which will be the object of all effort and dedication until the final reading of this doctoral thesis.

For decades in soccer, monitoring of movements performed by players during training or competition is being a topic of interest to sport scientists. The monitoring made possible to know the physical requirements to which the players are subjected, allowing a specific intervention in the training, control of what was done to avoid overloads or injuries and evaluate performance during competitions.

Taking advantage of the technological advance, the optimization of the performance of soccer players has acquired a growing role due, in part, to the use of GPS devices, to describe the physical demands. In this line of work, the current project supposes the possibility of advancing and innovating in soccer, since to date there is no study published in this sport regarding the physical and physiological demands measured with GPS technology during official matches.

This thesis is composed by different parts: one theorical and one experimental.

In the first part of the document, it is included a review of the literature, composed of several sections that analyze the different contents treated in the thesis.

The second part includes the 3 studies we have done, which are presented in an article format. The three studies are based on the analysis of movement patterns and physiological demands of professional soccer players during official competition, examining their distances traveled at different running intensities, their physiological response monitored through heart rate, differences by specific positions according to their role, and variability from match to match.

All these studies have been carried out, with the aim of obtaining a greater knowledge and understanding in the analysis of the different patterns of movement executed by the elite soccer players during official matches.

Capítulo 1 (Chapter 1)

This chapter describes the current status of the question, making a conceptual approach related to the running displacements that are made by the players in official competition. Detailing the techniques used so far for this analysis as well as the most relevant studies. Trying to contribute the most important aspects that relate to our analysis objective.

Capítulo 2 (Chapter 2)

This chapter contains the first study of the doctoral thesis, where it is quantify for the first time the physical and physiological profile of professional soccer players in official games using GPS and heart rate response, quantifying the dose-response of the match stimulus (external and internal load).

The main findings of the present study reflected that 1) playing position impacted significantly on relative distance covered, work-to-rest ratio, sprinting performance results and average HR, and 2) relationships between external and internal load measures among position-specific players indicated that those with less overall running performance during match-play showed the worst results in Eff_{index}.

Nevertheless, the present study reflects the specific demands during match-play (official games) in professional soccer players using GPS devices, and can be used to develop position-specific training tasks based on this tactical formation. Also, the work-to-rest ratio obtained can also help coaches to plan specific intermittent exercises and training protocols.

Capítulo 3 (Chapter 3)

This chapter contains the second study of the doctoral thesis, where it is quantified for the first time to our knowledge the internal and external loads of elite professional soccer players during full official matches using GPS and HR response. The main findings of the current study showed that 1) for all the playing positions, a substantial decrease in distance covered was reflected in the second half; 2) a greater distance was covered during the first 15 minutes compared with other periods of the match; 3) only 2^{nd}S and S had a substantially reduced HR during the second half (remained unchanged in others); and 4) Eff_{index} was substantially reduced in almost all the playing positions during the second half.

In addition, playing position impacted substantially on relative distance covered at different speeds, and relationships between external and internal load among position-specific players showed that those with higher overall match activity profile had the highest Eff_{index}.

Capítulo 4 (Chapter 4)

This chapter contains the third study of the doctoral thesis, where it is examined for the first time the match-to-match variation of physical performance in professional soccer players during official soccer matches over two consecutive season using GPS technology.

In the present study, we present for the first time GPS-derived data related to the variability of accelerations obtained during oficial games in elite profesional soccer players. Similar to the distance covered at different speeds, the number of accelerations performed at high accelerations was more variable than the number of low accelerations.

We provide also, for the first time, detailed GPS-derived match-to-match variability data on specific playing positions.

Our results show that 1) match-to-match CV ranged from 5.3% to 70% for the different locomotor variables, 2) the CVs were likely to increase with running/ acceleration intensity and 3) CVs were differently affected by playing position.

Capítulo 5 (Chapter 5)

After the experimental part, a series of conclusions, limitations and future lines of investigation common to these investigations are presented.

To conclude, and as a final annex, I add the three research articles in their original publication format in different JCR journals.

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Capítulo 2. Artículo 1

• **Match-play activity profile in professional soccer players during official games and the relationship between external and internal load**

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- **Variability of GPS-derived running performance during official matches in 15 elite professional soccer players (Under review)**

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Table 3. Between match variation of physical running performance (Playing positions) (Al Haddad et al. 2017)

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Capítulo 2. Artículo 1

• **Match-play activity profile in professional soccer players during official games and the relationship between external and internal load**

Figure 1. Average Heart Rate expressed in relation to the Individual maximal heart rate and Eff_{index} during the half in professional soccer players (Suarez Arrones et al. 2014)

Capítulo 3. Artículo 2

• **Relationship between external and internal loads of professional soccer players during full matches in official games using global positioning systems and heart-rate technology**

Figure 1. Match running profile in professional soccer players (Torreño et al. 2016)

ANTECEDENTES Y OBJETIVOS

(BACKGROUND AND OBJECTIVES)

Antecedentes (Background)

El presente apartado versa sobre una perspectiva de análisis y referencia conceptual que permita acercarnos al fútbol profesional. En concreto, al análisis de las demandas físicas y respuesta fisiológica durante partidos oficiales, como objeto de estudio desde una perspectiva original.

Estudios observacionales como los que se han desarrollado son potencialmente válidos para responder a hipótesis, siendo una herramienta óptima que nos ayudará a tener un mayor conocimiento del juego. De esa manera entendemos el valor y utilidad que tiene el análisis del juego, especialmente el análisis del juego durante la competición.

No cabe duda de que la tecnología está cada vez más presente en el deporte de alto rendimiento. El desarrollo y evolución del fútbol ha llevado parejo la implantación de nuevos sistemas en diferentes campos. La tecnología que se aplica al fútbol es cada vez más sofisticada y permite mejorar aspectos que influyen directamente en el rendimiento de los jugadores. Sobre todo, en la última década, ha crecido exponencialmente el análisis e investigación en fútbol basados en el control del entrenamiento, cuantificación de la carga y su relación con la competición oficial. Dentro del uso de estas tecnologías, actualmente el GPS es el método más empleado en fútbol de élite profesional para monitorizar y analizar los patrones de movimiento y carga locomotora durante las sesiones de entrenamiento. Sin embargo, es difícil obtener información sobre competición oficial a través de estos dispositivos, ya que generalmente la información de los partidos se monitoriza a través de sistemas multi-cámara, con las sustanciales diferencias entre tecnologías que esto supone, en cuanto al registro y análisis de los datos.

El fútbol es un deporte predominantemente aeróbico, intercalado con situaciones frecuentes de acciones de alta intensidad (J Bangsbo, 1994; M. C. Varley & Aughey, 2013). Entender las demandas físicas que se producen durante la competición es importante para optimizar el proceso de entrenamiento, ya que dichos entrenamientos deberán ser diseñados de acuerdo con las demandas observadas (Casamichana, Castellano, & Castagna, 2012).

A lo largo de los años, se han utilizado numerosas técnicas para determinar el perfil locomotor de los futbolistas en competición (V. Di Salvo et al., 2007; Mallo

& Navarro, 2008). En este contexto, la reciente introducción de la tecnología GPS para monitorizar tanto los entrenamientos como la competición, proporciona una medida fiable y válida en el análisis de las demandas locomotoras (Coutts & Duffield, 2010; Petersen, Pyne, Portus, & Dawson, 2009). A través de esta tecnología GPS podremos comprobar cómo el perfil locomotor de un jugador de fútbol en competición es diferente según la posición en la que juega (M. Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010a; Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013), o las diferencias que se pueden dar entre los diferentes entornos competitivos y el de entrenamiento (Casamichana et al., 2012).

Aunque los dispositivos GPS ya llevan años utilizándose durante el entrenamiento por numerosos clubes profesionales de fútbol, existe muy poca información disponible sobre su aplicación al estudio de perfiles físicos en jugadores durante partidos oficiales. Estudios previos han utilizado dispositivos GPS para describir el perfil locomotor en jóvenes jugadores de fútbol de diferentes categorías de edad (M. Buchheit et al., 2010a; Mendez-Villanueva et al., 2013), en jugadores de fútbol semi-profesionales durante partidos amistosos (Casamichana et al., 2012), o el perfil de aceleración en jugadores australianos de fútbol (M. C. Varley & Aughey, 2013). Hasta la fecha de la publicación del artículo presentado en el Capítulo 2, no existía información alguna que describiese los patrones de movimiento e intensidad fisiológica con futbolistas profesionales de élite, utilizando tecnología GPS y FC durante partidos oficiales.

El análisis de los patrones de movimiento es comúnmente usado por los científicos para evaluar el rendimiento locomotor (Ermanno Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009), y conocer las demandas de entrenamiento en deportes de equipo. Se pueden usar una variedad de métodos para monitorizar el perfil de actividad y la carga de los jugadores durante los partidos y entrenamientos. Los GPS son ahora ampliamente utilizados en la práctica en muchos deportes para evaluar la carga externa de los jugadores, ya que se ha demostrado que proporcionan una medida fiable y válida del perfil de actividad locomotora (Coutts & Duffield, 2010). La carga interna de los jugadores es comúnmente monitorizada usando medidas fisiológicas y/o perceptivas tales como la frecuencia cardiaca y la percepción del esfuerzo percibido. Al describir los cambios en las relaciones entre cargas internas y externas durante la competición y el entrenamiento, podemos facilitar el entendimiento de los cambios en el rendimiento físico del jugador o su estado de forma. Pocos estudios han examinado tanto la carga interna como la externa en deportes de equipo durante la competición y el entrenamiento (Kempton, Sirotic, & Coutts, 2015; Suarez-Arrones et al., 2014).

Hasta la fecha de publicación del primer artículo presentado en el Capítulo 2, no hay ningún dato en el que se relacione la carga externa y la carga interna de jugadores profesionales durante partidos oficiales de fútbol.

Aunque existe variedad de artículos publicados sobre los patrones de movimiento en fútbol durante el entrenamiento (Casamichana et al., 2012), como ya previamente manifestamos, existe información limitada sobre los patrones de movimiento de jugadores durante partidos oficiales medidos con dispositivos GPS (Barbero-Alvarez, Boullosa, Nakamura, Andrin, & Castagna, 2012; Martin Buchheit et al., 2014; Casamichana et al., 2012; Duffield, Coutts, McCall, & Burgess, 2011; Suarez-Arrones et al., 2014; M. C. Varley & Aughey, 2013). La mayoría de los artículos con jugadores de fútbol de alto nivel se han realizado a través de sistemas de cámaras semiautomáticas. Unos de los principales beneficios de usar la tecnología GPS y FC durante la competición, es la capacidad de proporcionar información en tiempo real sobre los desplazamientos (por ejemplo, distancia y velocidad) e intensidad del ejercicio por parte de los jugadores de campo a sus entrenadores. Por otro lado, permitirá comparar fácilmente los datos de los ejercicios empleados durante los entrenamientos con los de competición usando la misma tecnología. De esta manera, en base a las diferencias sustanciales existentes entre tecnologías de análisis del movimiento, se podrá llevar a cabo una aproximación mucho más rigurosa y fiable a la competición.

En un esfuerzo por comprender mejor las demandas del fútbol en los partidos oficiales, se ha realizado diversos estudios usando sistemas de cámaras semiautomáticas, donde se han descrito los patrones de actividad y las diferencias que se han producido durante primera y segunda parte (Bradley et al., 2009; V. Di Salvo et al., 2007; V. Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009a; E. Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Aunque algunos estudios no han encontrado diferencias entre las mitades de partido (Di Salvo et al., 2007; Varley, Gabbett, & Aughey, 2014), la mayoría de los estudios detectaron una disminución en las distancias totales y las distancias a alta intensidad en la segunda parte en comparación con la primera parte (Bradley et al., 2009; V. Di Salvo et al., 2009a; Mohr, Krustrup, & Bangsbo, 2003; E. Rampinini et al., 2007). Del mismo modo, e independientemente de la posición del jugador, se han encontrado reducciones en la distancia total y distancias cubiertas a velocidades más altas, medidas en períodos de 15 minutos de juego (Bradley et al., 2009; Mohr et al., 2003; Mohr, Krustrup, & Bangsbo, 2005).

Estos cambios en el patrón de actividad se deben a una combinación de la disminución del rendimiento del jugador y ajustes tácticos que se dan durante la competición. Sin embargo, muchos de estos estudios son limitados, ya que es difícil identificar claramente la disminución del rendimiento condicional del jugador en ausencia de información de carga interna.

La evaluación de la variabilidad partido a partido en los patrones de actividad derivados de sistemas GPS durante la competición, es de gran interés para comparar e interpretar la información registrada durante el entrenamiento en fútbol. De esta manera, esta variabilidad reflejada partido a partido deberá tenerse en cuenta cuando se analicen los entrenamientos basados en las demandas de competición.

Objetivos (Objectives)

A continuación se detallan los objetivos que se pretende conseguir con la realización del presente trabajo, dividiéndolos en dos tipos: objetivo general y objetivos específicos.

Objetivo General

Conocer y cuantificar por primera vez los patrones de movimiento e intensidad del ejercicio, a través de tecnología GPS y respuesta de la frecuencia cardiaca, en jugadores de fútbol profesional durante partidos oficiales.

Objetivos Específicos

El objetivo general se divide a su vez en una serie de objetivos específicos, que serán atendidos en cada uno de los capítulos que se presentan en esta tesis doctoral. Alcanzar estos objetivos específicos permitirá conocer de forma más detallada las demandas físicas durante competición oficial:

• **Objetivo Específico 1:**

Establecer el estado actual de la cuestión mediante una revisión bibliográfica acerca del fútbol, de las técnicas utilizadas en el análisis del movimiento, y de los estudios más relevantes realizados hasta la fecha en los cuales se haga referencia a nuestra temática abordada.

• **Objetivo Específico 2:**

Cuantificar, por primera vez, el perfil físico y fisiológico de los jugadores de fútbol profesional durante partidos oficiales mediante tecnología GPS y la respuesta de la frecuencia cardiaca, cuantificando la dosis-respuesta del estímulo de partido (carga externa e interna).

• **Objetivo Específico 3:**

Cuantificar, por primera vez, la carga interna y externa en jugadores de fútbol profesional de élite durante partidos oficiales completos usando GPS y FC, estableciendo posibles diferencias entre la primera y segunda parte.

• **Objetivo Específico 4:**

Conocer las diferencias de los patrones de movimiento y demandas fisiológicas durante partidos oficiales según la demarcación específica del jugador en el partido.

• **Objetivo Específico 5:**

Conocer, por primera, vez la variación en los patrones de movimiento partido a partido, con jugadores de fútbol profesional y durante partidos oficiales a lo largo de dos temporadas consecutivas, empleando para ello tecnología GPS.

CAPÍTULO 1. MARCO TEÓRICO

(CHAPTER 1. THEORETICAL FRAMEWORK)

"Soccer is not a science, but science can improve the level of soccer"

JENS BANGSBO

Aproximación conceptual

El fútbol está considerado como el deporte más popular del mundo, caracterizado por un importante nivel de complejidad, donde se da una constante de cooperación-oposición y demandas fisiológicas diversas, las cuales varían notablemente durante el transcurso de un partido. Esto es debido a diversas variables situacionales como el nivel de competencia, estilo de juego, posición en el campo o factores ambientales, entre otras (Carlos Lago, Casais, Dominguez, & Sampaio, 2010). Este deporte se desarrolla bajo un contexto aleatorio intermitente, dinámico y ágil, generando movimientos característicos de los deportes colectivos de colaboración-oposición, integrados dentro de una estructura del juego y lógica interna. El patrón del ejercicio en competición puede describirse como interválico y acíclico, donde se suceden entre 1000-1400 cambios de actividad a lo largo de un partido (Stølen, Chamari, Castagna, & Wisløff, 2005). De esta manera, esfuerzos de alta intensidad con naturaleza intermitente se superponen sobre una base de ejercicios de baja o moderada intensidad, ante recuperaciones generalmente incompletas (V. Di Salvo et al., 2007; Ziogas, Patras, Stergiou, & Georgoulis, 2011). El rendimiento del fútbol no solo depende de estos aspectos más fisiológicos, sino que existen diversos factores, posiblemente más determinantes, tales como técnicos, tácticos o mentales, entre otros, que también tienen una grandísima influencia en el rendimiento.

La metodología observacional, cuyo carácter científico esta claramente contrastado y avalado (Sackett, 1978; Suen, H. K., & Ary, 2014; Anguera, 1990; Riba, 1991; Bakeman & Gottman, 1997), constituye una de las opciones de estudio científico del comportamiento humano. Una correcta metodología observacional es fundamental para el análisis y conocimiento del deporte. En el caso del fútbol, nos encontramos ante un deporte muy complejo en el que intervienen muchos factores aislados de manera conjunta y simultánea. Durante las últimas cuatro décadas, se han desarrollado y empleado diversas metodologías de evaluación del rendimiento del futbolista en competición (Bangsbo, Nørregaard, & Thorsø, 1991). Se ha progresado de una metodología de estimación subjetiva y notacional para analizar los desplazamientos del jugador, a métodos mucho más avanzados de análisis tecnológico computerizado que nos informan de las diferentes acciones que el jugador lleva a cabo durante la competición (Barros et al., 2007; Bradley et al., 2009; V. Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009b). En base a esto, diferentes estudios intentan establecer posibles relaciones entre diferentes variables puramente condicionales, como la distancia recorrida, la velocidad a las que se realizan determinadas acciones, la duración de los diferentes esfuerzos, o la velocidad máxima, con el propio rendimiento deportivo (Mohr et al., 2003; O'Donoghue, 2002; Zubillaga 2006; Randers et al., 2010).

Desde hace décadas, la monitorización de los movimientos desarrollados por los deportistas durante el entrenamiento o la competición esta siendo un tema de interés para los científicos del deporte (Carling, Bloomfield, Nelsen, & Reilly, 2008; Liebermann et al., 2002). El seguimiento realizado posibilita conocer los requerimientos físicos a los que son sometidos los jugadores durante la competición (Barbero, Soto, & Granda, 2005; Rienzi, Drust, Reilly, Carter, & Martin, 2000), permitiendo esto intervenir de una forma más específica y adaptada en los entrenamientos (Barros et al., 2007). En este sentido, diversas tecnologías se han utilizado para el registro del movimiento de los deportistas, donde laboriosas técnicas de registro manual (Reilly y Thomas, 1976), han ido evolucionando hacia grabaciones magnetofónicas (Mayhew & Wenger, 1985; O'Donoghue, Boyd, Lawlor, & Bleakley, 2001), tabletas digitales (Partridge, Mosher y Franks, 1993), o softwares más específicos (Bloomfield, Polman, O'Donoghue, & McNaughton, 2007; Rienzi et al., 2000), para finalmente llegar a los sistemas más modernos como las técnicas de registro semiautomático a través de multi-cámaras de video. Entre estos últimos, podemos destacar el sistema Amisco® francés (J. Castellano, Blanco-Villaseñor, & Álvarez, 2011), o el ProZone® inglés (V. Di Salvo et al., 2009a), siendo los más empleados en la literatura científica.

El objetivo primordial del entrenamiento es la mejora del rendimiento competitivo. En ese sentido, la cuantificación del entrenamiento es de vital importancia de cara a programar cargas de entrenamiento mediante ejercicios específicos, que permitan una preparación óptima del deportista para la competición. Para ello se hace imprescindible, en primer lugar, el conocimiento de las exigencias de cada especialidad a través de un análisis profundo, riguroso y sistemático de la competición. Este análisis nos proporcionará valiosa información para diseñar tareas condicionales específicas. En segundo lugar, un adecuado control del entrenamiento y cuantificación de las cargas a las que son sometidos los jugadores. De esta manera, un mayor conocimiento y control sobre el tipo de esfuerzos, junto con las exigencias que implican las diferentes tareas y ejercicios que se realizan durante los entrenamientos, permitirá una planificación más rigurosa y una mejor dosificación de los esfuerzos y posible fatiga acumulada.

El rendimiento en fútbol de élite es multidimensional, y depende en buena forma de un elevado grado de desarrollo y especialización de todos los factores previamente mencionados. Garganta (1997) agrupa en cuatro dimensiones estos factores: la física, la técnica, la táctica y la psicológica. La gran mayoría de los estudios sobre factores de rendimiento en el fútbol han estado más enfocados al estudio de variables más puramente condicionales, aunque en los últimos años, han crecido exponencialmente líneas de estudio donde se busca relacionar variables físicas con diferentes contextos situacionales o factores técnico – tácticos (Casamichana & Castellano, 2014; J. Castellano et al., 2011; Carlos Lago et al., 2010).

El fútbol no es una ciencia, pero la ciencia puede ayudar y contribuir a mejorar el rendimiento en fútbol. Por ello, en las últimas décadas, ha habido grandes esfuerzos para intentar mejorar el rendimiento del fútbol centrándose sobre todo en mejorar sus diferentes áreas. Gracias a la aparición de nuevas tecnologías aplicadas al deporte, se ha avanzado sustancialmente en el registro de datos e información resultante tanto del entrenamiento como de la propia competición (Aughey, 2011).

Patrones de movimiento en fútbol y técnicas de registro semiautomáticas o videotracking

En los últimos años, la preocupación de mejorar el rendimiento de los jugadores a nivel individual, así como el rendimiento colectivo, ha propiciado un creciente interés en el análisis del comportamiento de los jugadores durante los entrenamientos y en competición.

El amplio abanico de técnicas utilizadas para ello, ha ido desde la observación y anotación en tiempo real, hasta el vídeo análisis computerizado realizado tras la finalización del partido. Los procedimientos semiautomáticos de monitorización de los jugadores, donde el soporte del vídeo es indispensable, es uno de los sistemas más empleados en el mundo del fútbol. Diferentes dispositivos han utilizado el videotracking como técnica para el registro de las variables locomotoras (espacio-tiempo), permitiendo conocer las zonas por donde los jugadores se desplazan, y a las velocidades que lo hacen durante el transcurso de la competición o entrenamiento.

Uno de los primeros trabajos que utilizó esta técnica para registrar los patrones de movimiento, fue publicado a finales de los años 80 cuando Van Gool, Van Gerven, y Boutmans (1988) filmaron un partido amistoso de fútbol en película de cine de 16 mm con una frecuencia de grabación de 5 Hz (5 imágenes por segundo), para posteriormente digitalizar los movimientos de todos los jugadores. Así, en las últimas dos décadas, ha cobrado especial relevancia el análisis de los jugadores a través de videocámaras que permiten analizar tanto datos técnico - tácticos como físicos, y que posteriormente pueden ser utilizados como herramientas de trabajo en los entrenamientos e incluso pueden servir para el diseño de tests (Ermanno Rampinini et al., 2009a; Ermanno Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009b; Randers et al., 2010).

La compañía francesa Amisco® y la inglesa ProZone® (actualmente fusionadas), dan servicio en las principales ligas europeas. Otras compañías también usan el sistema pasivo de tecnologías como el Tracab® (Suiza), Verusco® (Nueva Zelanda) y VenatrackTM (Inglaterra) (Redwood-Brown, Cranton, & Sunderland, 2012). Actualmente siguen proliferando programas informáticos, lejos de la perspectiva de prestación de servicios de Amisco y ProZone, pudiéndose llevar a cabo registros semiautomáticos sin necesidad de agentes externos (Barros et al., 2007; Fernandes & Caixinha, 2004; Figueroa, Leite, & Barros, 2006a, 2006b). Estos sistemas semiautomáticos de análisis de la actividad del jugador han sido utilizados para describir las principales competiciones de fútbol europeo.

Estos avances tecnológicos en los sistemas de videotracking han propiciado un análisis exhaustivo tanto de jugadores como de los equipos en el fútbol de élite. La cantidad de información detallada, permite a entrenadores y preparadores conocer cuáles son las necesidades actuales y futuras, con el objetivo de incrementar el rendimiento. Los patrones de movimiento que se observan durante un partido de fútbol es una combinación de la implicación directa del jugador, en respuesta a las acciones de ataque-defensa de su equipo, las del equipo oponente, limitaciones tácticas impuestas por su posición en el campo, el modelo de juego tanto de su equipo como el contrario, más la voluntad del jugador en apoyar a sus compañeros de equipo en todo momento (Drust, Atkinson, & Reilly, 2007).

El verdadero objetivo de este análisis es poder controlar de manera cinemática los movimientos e intensidades de trabajo de un jugador durante la competición y entrenamiento. Según Campos Vázquez M.A. (2015), este análisis de las demandas de la competición puede ser un buen punto de partida para determinar qué cualidades físicas deben ser determinantes, con el objetivo de alcanzar un alto grado de rendimiento en cualquier disciplina deportiva. Es por ello que numerosas investigaciones en las últimas décadas han analizado los patrones de movimiento que se suceden durante un partido de fútbol, llegando incluso a establecerse valores de referencia para las diferentes variables analizadas. A través de la utilización de esta tecnología, podemos conocer la distancia recorrida en función de diferentes puestos específicos ocupados dentro del terreno de juego (Di Salvo et al., 2010), diferencias entre primeras y segundas partes en relación a variables asociadas al rendimiento físico del futbolista (Rampinini et al., 2009), posibles diferencias entre los equipos exitosos y menos exitosos (V. Di Salvo et al., 2009a; Rampinini et al., 2009), entre diversas competiciones (Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011), la variabilidad en las acciones realizadas a alta velocidad comparando diferentes partidos (Gregson, Drust, Atkinson, & Salvo, 2010), o el efecto que pueda tener en la distancia recorrida en una sucesión de partidos durante un breve espacio de tiempo (Lago-Peñas, Rey, Lago-Ballesteros, Casáis, & Domínguez, 2011).

En la Tabla 1 (Campos Vazquez, M.A., 2015) vemos un resumen de las diferentes técnicas de registro en la investigación de las demandas físicas en fútbol:

Tabla 1. Técnicas de registro empleadas en la investigación de las demandas físicas en fútbol

ESTUDIO	POBLACIÓN	COMPETICIÓN	TÉCNICAS DE REGISTRO
Mohr. et al. (2003)	Profesionales (Élite y sub-élite)	Liga Italiana	Video – cámaras
Rampinini et al. (2007)	Profesionales (Élite)	Liga Nacional (Europa) UEFA, Copa Nacional	Prozone
Di Salvo et al. (2007)	Profesionales (Élite)	Liga española Champions League	Amisco
Di Salvo et al. (2009)	Profesionales (Élite)	Premier League	Prozone
Buchheit et al.(2010a)	Jóvenes jugadores (Élite) Sub-13 / Sub-18	Amistosos Internacionales	GPS (1Hz) SPI Elite GPSports
Casamichana et al. (2012)	Semiprofesionales (Elite)	Amistosos	GPS (10Hz) MinimaX

Apoyándonos en diversos trabajos de investigación que se han realizado a través de esta tecnología empleando multi-cámaras, a lo largo de los 90 minutos de un partido de fútbol los jugadores cubren una distancia que oscila entre los 10 y los 12 km, a una intensidad media de aproximadamente el 70–75% de su consumo máximo de oxígeno (VO2máx) (J Bangsbo, 1994; Iaia, Rampinini, & Bangsbo, 2009; Williams, Abt, & Kilding, 2010), y cubriendo de 2 a 3 km mediante carrera a alta intensidad de desplazamiento (>15km·h^{-1}) (Iaia et al., 2009). Tendencias más actuales sobre el estudio del patrón locomotor de los jugadores en competición, incluyen la influencia de las variables contextuales o situacionales (Castellano, Blanco-Villaseñor, & Álvarez, 2011), las cuales permiten explicar cada vez mejor los diversos factores que condicionan variabilidad al análisis de la actividad del jugador de fútbol durante la competición.

Tradicionalmente, una de las mayores limitaciones de estos sistemas tenía que ver con la falta de inmediatez de la información ofrecida, ya que los resultados se retrasaban 24-36 horas después de la finalización del partido, cuestión que se va solventando con la mejora de la tecnología (Carling et al., 2008). Actualmente, el coste económico y de personal que suponen estos sistemas de videotracking son su principal desventaja. Además de exigir, en muchos de ellos, una instalación fija de cámaras en el campo de competición, imposibilitando obtener los datos de los jugadores de manera inmediata, siendo en la mayoría de los casos inviable el empleo de esta tecnología para monitorizar los entrenamientos. La representación gráfica únicamente en 2D, así como la falta de orientación de los jugadores, son también limitaciones de este sistema. Por otro lado, la labor interpretativa de las conductas del jugador queda en gran medida reducida.

Patrones de movimiento en fútbol y sistemas GPS

Como hemos visto anteriormente, el control y rendimiento deportivo está siendo estudiado en mayor profundidad, con el objetivo de aportar datos cada vez más valiosos para los técnicos. La tecnología está siendo utilizada cada vez más por los cuerpos técnicos de los deportes de equipo como herramientas para el análisis de los desplazamientos, intensidad del ejercicio y control de la carga de entrenamiento. En la actualidad, existen muchas técnicas e instrumentos que están siendo empleados con este objetivo. De todos los sistemas de registros de datos para el análisis y control de la competición y entrenamientos, los dispositivos a través de tecnología GPS resultan los que más aplicación están obteniendo en los deportes de equipo y más concretamente en el fútbol. La monitorización de los patrones de movimiento a través de la tecnología GPS, junto un monitor de frecuencia cardíaca y un acelerómetro, permite obtener información sobre la posición, distancias recorridas, tiempo y velocidad a la cual se desplazan los jugadores durante entrenamientos o partidos, además de la respuesta de su frecuencia cardiaca. Esta información la podemos adquirir de forma paralela con varios jugadores al mismo tiempo y con la posibilidad también de obtener datos en tiempo real.

El GPS es uno de los métodos más utilizados en los deportes colectivos para analizar los patrones de movimiento y las cargas de trabajo (Hulin, Gabbett, Kearney, & Corvo, 2015; Polley, Cormack, Gabbett, & Polglaze, 2015; Matthew C. Varley et al., 2014). Para poder realizar dichos análisis, los deportistas han de llevar durante el entrenamiento o la competición dispositivos GPS portátiles, que se introducen en un peto, concretamente en un bolsillo situado en la espalda de los jugadores. A día de hoy, encontramos que los dispositivos GPS son pequeños y ligeros, con una buena capacidad de almacenamiento, permitiendo una buena adaptación a los deportes de equipo jugados en el exterior, como es el caso del fútbol. A través de estos dispositivos podemos monitorizar numerosas variables relacionadas con la carga externa como distancia total, distancia relativa, desplazamientos a diferentes velocidades o aceleraciones y deceleraciones, entre otras (Cummins, Orr, O'Connor, & West, 2013). El uso primario y más común de estos dispositivos en el mundo del deporte (especialmente en deportes de situación), ha sido describir los desplazamientos que realizan los deportistas durante la competición. Extendiéndose el uso de esta tecnología a multitud de deportes como el fútbol (Barbero-Álvarez, Barbero-Álvarez, Gómez, & Castagna, 2009; M. Buchheit et al., 2010a; Harley et al., 2010), en un intento de analizar el patrón locomotor del deportista durante la competición, detectar la posible fatiga durante los partidos, evaluar la capacidad condicional del deportista o monitorizar diferentes tareas de entrenamiento (Aughey, 2011).

De forma más específica, el GPS puede ser utilizado para (McLellan, Lovell, & Gass, 2011):

- Cuantificar objetivamente los niveles de esfuerzo y estrés físico de cada deportista.

- Examinar el rendimiento locomotor en la competición.

- Evaluar las diferentes cargas de trabajo dependientes de la posición en el terreno de juego.

- Analizar las intensidades de entrenamiento.

- Evaluar los cambios en las demandas fisiológicas del jugador.

Las prestaciones de los dispositivos GPS a lo largo de los últimos años han ido mejorando, siendo actualmente la mayoría de ellos capaces de proporcionar un detallado análisis en tiempo real del rendimiento locomotor de los jugadores (Cummins et al., 2013).

Además, estos dispositivos también han sido empleados para conocer la respuesta endocrina, inmunológica y daño muscular durante el partido (Thorpe & Sunderland, 2012), el efecto del nivel de capacidad física (Carlo Castagna, Impellizzeri, Cecchini, Rampinini, & Barbero Álvarez, 2009; Carlos Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010), el estrés térmico (Özgünen et al., 2010), o la aplicación de diversos métodos de recuperación sobre el rendimiento en competición (Martin Buchheit, Horobeanu, Mendez-Villanueva, Simpson, & Bourdon, 2011; Rowsell, Coutts, Reaburn, & Hill-Haas, 2011). Más numerosas son las investigaciones que han utilizado el GPS en los deportes de equipo con el objetivo de detectar fatiga en partidos, identificar períodos de juego de elevada intensidad, conocer los diferentes patrones locomotores para cada puesto específico y nivel competitivo (Aughey, 2011).

Para sacarle aún mas partido a esta tecnología, podemos clasificar el movimiento en diferentes en rangos de velocidad, estableciendo umbrales absolutos o relativos al perfil locomotor del jugador, para, en base a estos, determinar acciones locomotoras de alta intensidad durante partidos o entrenamientos, así como la repetición de esas secuencias (Aughey, 2011; M. Buchheit et al., 2010a).

Con el paso de los años, los dispositivos GPS se han convertido en un medio adicional para describir y comprender el contexto espacial de la actividad física (Cummins et al., 2013), no siendo solo las demandas físicas las únicas beneficiadas de esta tecnología. A través de los datos brutos obtenidos a través del GPS y gracias a las diferentes aplicaciones informáticas, resulta posible conocer cómo se desarrolla el juego desde la perspectiva táctico-estratégica.

En esta línea, Sampaio & Maçãs (2012), han empleado los dispositivos GPS para conocer los datos posicionales dinámicos de los futbolistas, y como estos datos pueden ser usados para evaluar el comportamiento táctico midiendo los patrones de movimiento y la coordinación entre jugadores, en una tarea de 5 vs 5 con porteros. Otro estudio propone analizar la relación entre jugadores, equipos y su interacción (Duarte, Araújo, Correia, & Davids, 2012), a partir de variables como las superficies de juego que abarcan los equipos, centroide o centro geométrico del equipo, su grado de compactación, de profundidad o anchura del equipo.

A pesar de que los sistemas GPS han demostrado ser un método válido para determinar la posición de un sujeto durante estudios biológicos y biomecánicos (Schutz & Chambaz, 1997; Schutz & Herren, 2000; Terrier, Ladetto, Merminod, & Schutz, 2000; Terrier & Schutz, 2003; Witte & Wilson, 2004), todavía cuenta con algunas limitaciones para su uso, fundamentalmente respecto a su fiabilidad, la cual debe ser aún optimizada.

La validación adicional del GPS para el deporte de equipo no ocurrió hasta 2009-2010, con una serie de estudios que emplearon la tecnología GPS para analizar desplazamientos similares a los que los jugadores realizan durante la competición (Aughey, 2011; Coutts & Duffield, 2010; Portas, Harley, Barnes, & Rush, 2010). Una comparación directa a través de estos estudios es difícil, si el objetivo es una declaración para respaldar la validez del GPS en los deportes de equipo, debido a la variedad de dispositivos GPS, de tareas, ejercicios analizados, frecuencias de muestreo y métodos estadísticos aplicados (Aughey, 2011). La fiabilidad del GPS para determinar análisis cinemático de los deportistas está influenciada por diferentes factores: la frecuencia de muestreo, la duración de la tarea y el tipo de tarea, (Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., & Aughey, 2010; Jennings, Cormack, Coutts, Boyd, & Aughey, 2010; Portas et al., 2010). El efecto que se produce por una mayor o menor frecuencia de muestreo, hace que el GPS ofrezca resultados ambiguos en cuanto a su fiabilidad, la cual dependerá de la potencialidad del dispositivo (Aughey, 2011). Los primeros estudios nos muestran como el coeficiente de variación (CV) de un sprint de 10 m fue del 77% con 1 Hz GPS y 39.5% con 5 Hz, sin embargo, en las tareas de fútbol más o menos lineales, el CV fue 4.4 - 4.5% de 1 Hz y 4.6 5.3% para 5 Hz (Aughey, 2011; Portas et al., 2010). Menos ambigüedad encontramos en la afirmación relacionada con que cuanto mayor sea la velocidad de movimiento, menor será la fiabilidad del GPS. El CV aumentó de 30.8% a 77.2% para un sprint de 10 m en comparación con caminar sobre la misma distancia medida con GPS de 1 Hz. Usando un GPS de 5 Hz , el CV aumentó 23.3% a 39.5% para la misma tarea a las mismas velocidades (Aughey, 2011; Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., & Aughey, 2010; Jennings et al., 2010).

Varios estudios han establecido una buena validez para el GPS de 1 Hz en el establecimiento de la distancia total obtenida durante una actividad de movimiento simulado de deportes de equipo (Aughey, 2011; Portas et al., 2010). La fiabilidad de los ensayos lineales y específicos de fútbol en los dispositivos de 1 Hz y 5 Hz estuvieron dentro del 5% de coeficiente de variación, que le hacen cumplir con los criterios establecidos como fiables en estudios similares (Portas et al., 2010).

Varias investigaciones coinciden en afirmar que cuanto mayor sea la velocidad de muestreo del GPS, más válido será para medir la distancia recorrida, sobre todo a altas velocidades (Coutts & Duffield, 2010; Duffield, Reid, Baker, & Spratford, 2010). Si comparamos tareas similares de alta velocidad realizadas en distintos estudios, comprobamos como el error en la distancia estimada es mayor en dispositivo GPS de 1 Hz que en uno de 5 Hz (Aughey, 2011), mientras que en este es mayor que el obtenido en un GPS de 10 Hz (Aughey, 2011; Julen Castellano & Casamichana, 2010). Además, investigadores y profesionales deben tender a utilizar GPS con una mayor tasa de muestreo para mejorar la validez y fiabilidad de los resultados obtenidos.

Los sistemas GPS en fútbol han sido poco utilizados en competición oficial. Hasta la fecha, su uso ha sido primordialmente en estudios que analizan los patrones de movimiento durante partidos amistosos con jugadores semi-profesionales, o con jugadores jóvenes de varias categorías (M. Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010a; Casamichana et al., 2012). Principalmente, donde sobre todo se han utilizado estos dispositivos es para monitorizar el proceso de entrenamiento, análisis de ejercicios y cuantificación de cargas (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Esto ha sido debido a que hasta hace poco tiempo, no era posible su uso en la mayoría de competiciones internacionales o ligas de fútbol.

La monitorización de los jugadores en el entrenamiento permite conocer en qué medida el entrenamiento replica las demandas impuestas a los jugadores por la competición (Casamichana & Castellano, 2011). En esta línea, previos estudios informan que en general, durante los entrenamientos, difícilmente de reproducen las demandas locomotoras a alta velocidad, a las cuales los jugadores sí son sometidos durante los partidos (Casamichana & Castellano, 2011; Dawson, Hopkinson, Appleby, Stewart, & Roberts, 2004; Hartwig, Naughton, & Searl, 2011).

En definitiva, la metodología GPS nos permitirá monitorizar y evaluar, para una mayor comprensión, datos del comportamiento de los jugadores tanto en competición como durante los entrenamientos. Esta información, dentro de un contexto propio de cada equipo y modelo de juego, la podemos utilizar para:

- Modificar el tipo, la duración, la intensidad y la especificidad individual de cada ejercicio, mejorando así la totalidad de las sesiones de entrenamiento.

- Analizar las demandas de las tareas de entrenamiento para individualizar determinadas cargas de trabajo de los jugadores del mismo equipo, con el objetivo de optimizar el proceso de planificación y prevenir lesiones.

-Diseñar tareas adaptadas a los jugadores y a sus perfiles de actividad locomotora en competición, siempre dentro del contexto de juego.

Hasta la fecha de publicación de los artículos que integran la presente tesis doctoral, ninguna investigación previa había empleado los sistemas GPS, para caracterizar los desplazamientos de jugadores de fútbol de élite profesional durante partidos de competición oficiales.

Fútbol y complejidad: variables situacionales que afectan a los patrones de movimiento

El fútbol es considerado como un deporte sumamente complejo. Durante un partido suceden muchas situaciones cuya frecuencia, orden cronológico y complejidad no pueden ser previstas, exigiendo un alto grado de adaptabilidad y respuesta inmediata por parte de los jugadores y los equipos, a partir de los conceptos de oposición en cada fase del juego (Garganta, 1997).

No conocemos análisis profundos que muestren el entramado de relaciones entre los distintos componentes que interactúan en el desarrollo de un partido, ya que tradicionalmente, se ha realizado siempre un acercamiento reduccionista examinando al fútbol de manera aislada, sin integrar otros factores. Ha sido analizado siempre desde áreas con mayor tradición investigadora como la medicina, la fisiología o la psicología, lo que provoca que el estudio de factores de rendimiento en fútbol haya estado enfocado principalmente desde estas áreas y mucho menos desde el análisis del juego.

En los últimos años han sido publicados varios estudios (Lago-Peñas, 2012; Paul, Bradley, & Nassis, 2015a) referidos a diversas variables situacionales o contextuales que pueden influir sustancialmente en el rendimiento locomotor del jugador. Según Lago (2008), en los deportes de tanteo bajo (fútbol, hockey hierba), la propuesta de los indicadores del rendimiento que contiene el desarrollo del juego es mucho más difícil de seleccionar. La finalización, independientemente de su consecuencia, es en sí mismo un indicador de éxito dentro del juego. La identificación de las causas que condujeron a la evolución del partido y al resultado final resulta muy compleja. A veces, una causa pequeñísima (una decisión arbitral, un cambio en la alineación) provoca un efecto considerable en el juego, y otras veces, una causa aparentemente enorme (una expulsión, un gol), no tiene apenas consecuencias perceptibles. La varianza del resultado en diferentes partidos de fútbol, surge, por una parte, de las diferencias sistemáticas que son persistentes e incluyen características fundamentales y predecibles de los equipos como su planteamiento táctico, la apuesta por el dominio de la posesión del balón o no, la calidad individual de los jugadores, o el tipo de defensa seleccionada. Por otra parte, surge de las diferencias no sistemáticas, que son transitorias, no podemos predecir su impacto, como los cambios producidos por alteraciones meteorológicas o los errores arbitrales.

Una cuestión que debe ser considerada es que no todos lo equipos tienen el mismo modelo de juego, ni pretenden dominar los mismos aspectos del partido. Esta característica determina que la selección de los indicadores a utilizar para valorar el rendimiento de los equipos, deba ser específica e individual para cada equipo. No pueden ser utilizados los mismos indicadores del rendimiento en dos equipos que tienen diferentes objetivos de juego (Lago y Martín Acero, 2005). En definitiva, los mismos indicadores del rendimiento, pueden tener una potencia explicativa muy diferente para dos equipos distintos o para un mismo conjunto en dos momentos de la competición diferentes.

Dado que el fútbol está dominado por factores estratégicos, es razonable sugerir que las variables situacionales pueden, de alguna manera, influir en las actividades de los equipos y de los jugadores. Los investigadores deben incluir variables situacionales en sus modelos explicativos para entender mejor por qué las demandas físicas varían a lo largo del juego. Como hemos visto a lo largo de los apartados anteriores, el análisis de los patrones de movimiento, ya sea a través de sistemas de videotracking o GPS, es una valiosa técnica de recopilación de datos utilizada para cuantificar los desplazamientos de los jugadores en el fútbol de élite. Sin embargo, estos sistemas no miden las exigencias de la competición, sino solamente los movimientos que los jugadores ejecutan y a qué velocidades.

El análisis de la carga externa proporciona información valiosa sobre las necesidades fisiológicas y de rendimiento locomotor de los jugadores. Entrenadores y preparadores físicos utilizan medidas de distancia de partidos o ejercicios de entrenamiento para evaluar las demandas de trabajo y comparar el rendimiento locomotor de los jugadores (Jennings, D., Cormack, S., Coutts, A. J., Boyd, L., & Aughey, 2010; Jennings et al., 2010). Estos análisis han demostrado que la distancia total cubierta, o la distancia recorrida a alta intensidad, puede depender de factores como el puesto específico, el nivel de la competencia, la capacidad física del jugador, que el equipo tenga un mayor o menor porcentaje de posesión, o del rendimiento físico del oponente y su modelo de juego (Krustrup et al., 2003; Mohr et al., 2003; E. Rampinini et al., 2007; Domenech, C., 2015). Diversos estudios se centran en la importancia de estos factores situacionales, y como esto se refleja en los cambios en los patrones de movimiento de los jugadores, como respuesta a las situaciones que se van dando durante el partido (Bloomfield et al., 2005; James, Mellalieu, & Hollely, 2002; Jones, James, Mellalieu, 2004; Lago-Penas et al., 2009; Lago & Martín, 2007; Shaw and O´Donoghue, 2004; Taylor et al., 2008). Según Paul, Bradley, & Nassis, (2015b), además de todas estas variables situacionales se debe tener en cuenta la autogestión por parte del jugador, ya que el jugador regula sus esfuerzos durante el partido, o durante periodos del mismo, en función de las demandas que se van produciendo durante el juego (Carling et al., 2008; E. Rampinini et al., 2007).

a) Rol específico

En el fútbol actual, el concepto de equipo es algo más que la suma de los jugadores que lo componen, por ello, a la hora de hablar del rol del jugador nunca debemos perder de vista el conjunto. A lo largo de un partido de fútbol, los equipos se encuentran en una constante transición de diferentes situaciones de ataque a otras muchas situaciones en las que tendrán que defender. Esas transiciones que se dan a lo largo de un partido de fútbol, van a hacer que cada futbolista, en función del papel que le toque desempeñar dentro del equipo, tenga que realizar un tipo de esfuerzo u otro. Las diferentes funciones que se les otorgan a los jugadores en un equipo de fútbol son objeto de estudio por parte cuerpo técnico, con la finalidad de conocer cada una de las situaciones que se dan durante los partidos de competición y, con especial referencia, al rol que cada jugador desempeña durante el juego (Dellal et al., 2010).

En el estudio realizado por Dellal et al. (2010), muestran que las características físicas de los jugadores en base a la posición que ocupa en el terreno de juego varían en función del país y la liga en la que jueguen. Según Bloomfield et al. (2007), estos esfuerzos de los jugadores en la FA Premier League, además de las diferentes exigencias físicas en función de los diferentes puestos específicos, dependerán de la posición del balón y del área de influencia del futbolista sobre el esférico (Bloomfield et al., 2007). En este sentido, el rol posicional parece tener una influencia sobre el gasto total de energía de un jugador en un partido, sugiriendo diferentes requerimientos físicos, fisiológicos y bioenergéticos (Bloomfield et al., 2007).

Para conocer cuáles son las características de los esfuerzos que realizan los futbolistas dependiendo de su posición dentro del equipo, encontramos un trabajo (Dellal et al., 2010) en el que se concluye que los defensas centrales son los que recorren una menor distancia, mientras que los delanteros son los que realizan el mayor número de sprints. Otro estudio de similares características, (V. Di Salvo, Pigozzi, González-Haro, Laughlin, & De Witt, 2013) establece una diferencia entre centrocampistas y centrocampistas de banda, otorgándoles a estos últimos mayor número de sprint, al igual que resalta que los delanteros y laterales, son los que mayor número de sprints cortos (hasta 10 m) realizan. La literatura hace otras aportaciones, tales como que un centrocampista recorre una mayor distancia a media y baja intensidad durante el desarrollo de un partido, al tratarse de un rol que ha de ser el enlace entre la defensa y la delantera (Bloomfield et al., 2007; Dellal et al., 2010). Basándonos en las diferentes aportaciones científicas, conocemos que el rol específico durante el partido va a determinar el número y tipo de acciones predominantes para ese jugador, siendo por ejemplo una de las acciones más habituales en el rol del delantero saltar para golpear el balón con la cabeza, mientras que los defensores se verán involucrados en un mayor número de contactos. En esta línea, Bloomfield et al. (2007) encontraron diferencias en los movimientos realizados por los defensas, medios y delanteros a lo largo de un partido de la Premier League inglesa. Los defensas realizaron un mayor número de desplazamientos, saltos y deslizamientos, pero sus acciones de alta velocidad fueron significativamente menores a las de otras posiciones. Los mediocampistas cubrieron una mayor distancia general durante los partidos, pasando un tiempo significativamente menor andando o detenidos que los delanteros o defensores, pero durante más tiempo realizando acciones de moderada velocidad. Esto contrasta con los esfuerzos desempeñados por los delanteros, que realizan significativamente más acciones de alta velocidad que los centrocampistas. Los delanteros también tienen que ser jugadores físicamente más fuertes ya que realizan muchas acciones en las que entran en contacto físico con los defensores rivales, además de tener mayor capacidad para realizar una parada tras una acción de alta intensidad, de la misma forma que registran valores más altos para hacer cambios de direcciones y desaceleraciones de una manera más rápida (Bloomfield et al., 2007). En esta línea, otro estudio informa que los delanteros realizan el 66% de los desplazamientos a alta velocidad, siendo los que más distancia recorren en este tipo de acciones (Dellal et al., 2010).

b) Resultado del partido

En el fútbol, el resultado es visto como una medida de rendimiento y puede influir en el esfuerzo realizado por un jugador (O´Donoghue and Tenga, 2001), reflejando posibles cambios en su comportamiento en función de si su equipo va ganando, perdiendo o empata (Bloomfield et al., 2005; Taylor et al., 2008). Se ha demostrado que los jugadores de fútbol realizan significativamente menos actividad de alta intensidad cuando ganan, que cuando pierden o cuando el marcador está nivelado (Bloomfield et al., 2005; J. Castellano et al., 2011; Shaw and O´Donoghue, 2004; O ´Donoghue and Tenga, 2001). Estos resultados sugieren que los jugadores no siempre usan su máxima capacidad física durante el partido, autorregulándose (Carling et al., 2008; E. Rampinini et al., 2007). Cuando los jugadores van perdiendo, generalmente intentan alcanzar su máxima actividad para ganar o empatar el partido, existiendo diferencias en el rendimiento locomotor de los futbolistas de élite en función de si ganan, empatan o pierden (Aughey, 2011). En este sentido, se hace complicado en muchos casos detectar, si es la fatiga la causante cuando el jugador reduce sustancialmente su rendimiento locomotor, o si por el contrario, es la autogestión del propio jugador, provocada por factores contextuales o situacionales, la culpable de esta disminución en sus desplazamientos (Aughey, 2011a; Duffield, Coutts, & Quinn, 2009).

c) Nivel del rival

Otra de las razones por las que podemos encontrar un descenso en los patrones motores de algunos jugadores o del equipo, puede ser la repetida presión o dominio que ejerce un rival, ya sea individual o colectivo, lo cual eventualmente conduce a una incapacidad para responder a las demandas del juego (Lago, 2009; E. Rampinini et al., 2007; Zubillaga et al., 2007). En esta línea, Rampinini et al. (2007) observaron que el ratio de trabajo de los jugadores profesionales de fútbol fue significativamente influenciado por el nivel de los oponentes. El estado de fatiga de un jugador durante el juego, aparece y desaparece en base al tiempo de recuperación disponible y el estado de forma del jugador, una vez que la presión del rival desaparece. Rampinini et al. (2007), mostraron que la distancia total recorrida y los esfuerzos de carrera a alta velocidad durante partidos contra rivales de mayor nivel, son más elevados que contra rivales más débiles. Otros estudios con similares resultados, sugieren que cuando menor es la calidad del oponente, menor es la distancia recorrida por el equipo observado (Bloomfield, 2005; Lago et al., 2010), argumentando que los jugadores pueden aumentar o disminuir su ratio de trabajo, dependiendo de las demandas individuales del partido o del nivel del rival.

d) Jugar como local o visitante

Diversos estudios han analizado el comportamiento del equipo cuando juega de local/visitante, y si esto, tiene algún tipo de relación con los patrones de movimiento de los jugadores en competición. Los resultados de algunos estudios muestran que los equipos que juegan como locales, cubren más distancias a baja intensidad que cuando juegan como visitante (Lago et al., 2010; Lago-Peñas et al., 2009; Zubillaga et al., 2007). Algunos autores sugieren que los efectos de este factor deben estar relacionados con otras variables situacionales, como por ejemplo, jugar como local y contra un rival más débil o más fuerte (Castellano et al., 2011). A pesar de que sabemos, y está bien documentado que jugar como local tiene unas ventajas, principalmente motivacionales (Brown Jr et al., 2002; Clarke, Norman, & Clarket, 1995; Nevill & Holder, 1999), las causas precisas, su interacción con otras variables y su efecto en el rendimiento, no está aún claro.

e) Calendario congestionado de partidos

Varias investigaciones han mostrado el desgaste muscular y la reducción de la capacidad anaeróbica que supone jugar un partido, y como permanecen estos niveles, casi 72 horas después (Ascensão et al., 2008; Ispirlidis et al., 2008). Por tanto, en algunos casos se podría esperar una bajada del rendimiento físico en competición, debido a una disminución sustancial en diferentes parámetros fisiológicos, provocado por no existir una recuperación suficiente entre partidos. Recientemente diversos estudios, usando una sofisticada tecnología de medición, han analizado los perfiles de actividad física e índice de lesiones de la liga inglesa (Odetoyinbo, Wooster, & Lane, 2009), liga española (Lago- Peñas et al., 2009; Lago-Peñas et al., 2010; Rey, Lago-Peñas, Lago-Ballesteros, Casais, & Dellal, 2010) y liga escocesa (Dupont et al., 2010) en jugadores profesionales durante periodos de 2 o 3 partidos semanales. Inesperadamente, estos estudios no revelaron una diferencia estadística significativa en distancias recorridas a varias velocidades, aunque sí en el incremento de lesiones musculares (Dellal, Lago-Peñas, Rey, Chamari, & Orhant, 2015).

Interacción de las diversas variables situacionales

Un análisis aislado de todas las variables situacionales pueden aportar una visión limitada dentro de la naturaleza compleja del fútbol (McGarry and Franks, 2003; Reed and O´Donoghue, 2005). Lago et al. (2010) examinaron los efectos de diversas variables como jugar de local/visitante, el nivel del rival y efecto del resultado en relación a la distancia recorrida a diferentes velocidades en fútbol profesional. Como se puede ver en la Tabla 2 aportada por Lago et al. (2010), el rendimiento locomotor fue influido por dichas variables, tanto de manera independiente como con interacción entre ellas. En función de esto, la distancia cubierta a alta velocidad (23 km·h-1) por los jugadores, puede diferir considerablemente (~31%) según es el resultado del partido, el nivel del rival o si juegan de local/visitante.

Tabla 2. Simulated distance covered (m) at different speeds depending on match location, quality of opposition, and match status (Lago et al. 2010)

Match status	Quality of opposition	HOME MATCHES						AWAY MATCHES					
		TOTAL	0-11 km/h	11-14 km/h	14-19 km/h	19-23 km/h	+23 km/h	TOTAL	0-11 km/h	11-14 km/h	14-19 km/h	19-23 km/h	+23 km/h
Winning 90 min	Strong	11140	7050	1744	1649	481	217	10856	6911	1584	1653	453	189
Winning 90 min	Weak	10824	6727	1662	1665	540	231	10540	6587	1501	1669	512	204
Losing 90 min	Strong	10856	6853	1678	1653	555	281	10641	6713	1518	1629	527	253
Losing 90 min	Weak	10540	6529	1596	1669	614	295	10325	6390	1435	1646	586	268
Drawing 90 min	Strong	11068	6990	1725	1632	496	225	10766	6890	1565	1646	468	197
Drawing 90 min	Weak	10802	6710	1654	1641	555	242	10441	6550	1505	1659	518	209

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CAPÍTULO 2. ARTÍCULO 1

(CHAPTER 2. STUDY 1)

"Todos los entrenadores hablan sobre movimiento, sobre correr mucho. Yo digo que no es necesario correr tanto. El fútbol es un juego que se juega con el cerebro. Debes estar en el lugar adecuado, en el momento adecuado, ni demasiado pronto ni demasiado tarde"

JOHAN CRUYFF

Match-play activity profile in professional soccer players during official games and the relationship between external and internal load

Abstract

Aim: The aim was to quantify for the first time the physical and physiological profile of professional soccer players in official games using GPS and heart rate response. **Methods:** Thirty professional soccer players were investigated during a half in competitive club level matches (n=348) using GPS devices. **Results:** The relative total distance was 118.9±10.7 m·min^{-1} and player's work-to-rest ratio was 2.1:1. Defenders covered the lowest total distance, while Second-Strikers (2ndS) and Wide-Midfielders (W-MD) traveled the greatest total distance. Defenders presented the lowest work-to-rest ratio values. Playing position also impacted on all sprinting performance results, except in average sprint distance and time of sprint. The number of sprints and repeated-sprint sequences recorded by the W-MD and Strikers (S) were significantly greater than any other group. The average Heart Rate (HR) recorded was 87.1%HR_{max} and the relationship between the external and internal load value (Eff_{index}) was 1.4 with significant differences in both between playing positions. W-MD recorded a significantly smaller average HR than any other group and Centre-Backs showed a significantly smaller Eff_{index} value than any other group. Conversely, W-MD showed a significantly greater Eff_{index} value than any other group, except the 2ndS. **Conclusion:** This study has verified a number of statistically significant differences between the different playing positions. Coaches should be focused on the specific physical and physiological requirements of the playing positions to optimize the training prescription in soccer. The relationships between external and internal load measures among position-specific indicates that players with less overall running performance during match-play were the worst in Eff_{index}.

Keywords: team sport, time motion, GPS, football

Introduction

Football is a predominantly aerobic sport, interspersed with frequent bouts of high-speed movements (Bangsbo, 1994; Varley & Aughey, 2013). Understanding the physical demands of match-play is important in order to optimise the training process, since specific protocols can then be designed in accordance with these demands (Di Salvo et al., 2007).

Over the years, numerous techniques have been used to determine the physical profile of soccer players (Casamichana, Castellano, & Castagna, 2012; Di Salvo et al., 2007; Mallo & Navarro, 2008). In this context, the recent introduction of GPS technology for monitoring both training and competitive events provides a reliable and valid measure of the physical profile (Coutts & Duffield, 2010; Petersen, Pyne, Portus, & Dawson, 2009). Furthermore, the use of GPS looks set to increase our knowledge by revealing how a soccer player's physical profile evolves with age (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010a), how it varies according to the playing position (Buchheit et al., 2010a; Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2012), and between competitive versus training contexts (Casamichana et al., 2012). Due to the differences between video-based analysis system and GPS devices care should be taken when using data from them interchangeably to log the external load on soccer players (Li, Dallaway, & Daley, 2012; Randers et al., 2010).

Although GPS devices are now being used during training by numerous soccer clubs, very little information is available about their application to the study of physical profiles in players during competition. Some studies have used GPS devices to describe the physical profile among young soccer players in different age categories (Buchheit et al., 2010a; Mendez-Villanueva et al., 2012), semi-professional soccer players (Casamichana et al., 2012) in friendly matches, or acceleration profile in Australian soccer players (Varley & Aughey, 2013). No published studies have described the physical and physiological profile of European professional soccer players using GPS technology in official games. Accordingly, the aim of this study was to quantify for the first time the physical and physiological profile of elite European professional soccer players in official games using GPS and heart rate response, quantifying the dose-response of the match stimulus (external and internal load).

Materials and methods

Subjects

Time-motion analysis of running activity and heart rate response was collected in 30 elite European professional soccer players (~14h of training per week). The participants were informed in detail about the experimental procedures and the possible risks and benefits of their participation. The study was approved by the Research Ethics Committee of Pablo de Olavide University and written informed consent was obtained from all participants. Players were informed that they could refuse to participate in the study.

Experimental protocol

An observational design was used to examine the physical demands and exercise intensity in male soccer players during competitive matches using GPS technology and HR response. Thirty elite professional outfield players from the same team were investigated during competitive club level matches in the national league, national cup, and national super cup. Match analyses were performed 4-15 times on each player over a period of two seasons (n = 348). At the same time, the team also was participating in the Champions League or UEFA Europa League, depending on season. Tactically, the team used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a "second striker". In order to reduce possible fatigue, tactical changes or the possible influence of the result in the running performance during the second half, only the first half was analysed to describe movement patterns during match-play (45-min each plus additional time). Only time-motion data of players who participated in the entire half were retained for the subsequent analyses. GPS and heart rate (HR) data were used to provide quantitative information on match-play.

Activity pattern measurements

Players were required to wear a GPS unit (SPI Pro X; GPSports Systems, Canberra, Australia) during the game, which was fitted to the upper back (i.e., between the shoulder blades) of each player using an adjustable neoprene harness. The devices were switched on ~10 minutes before the game and immediately switched off at the end. The data stored includes HR, time, speed, distance, accelerations and impacts ("g" force). GPS data were recorded at 5 Hz and accelerometer data at 100 Hz respectively. The validity and reliability of the GPS system have been previously reported (Coutts & Duffield, 2010; Varley, Fairweather, & Aughey, 2012) and used in soccer players (Buchheit et al., 2010a; Casamichana et al., 2012; Mendez-Villanueva et al., 2012; Varley & Aughey, 2013).

Match running demands analysis

Only the time-motion data for players who participated in the entire first half were retained and only were analysed the minutes of the match-play. Time-motion data from all players were analysed with the software designed to provide objective measures of physical match performance. The players' activities were coded into five categories and speed thresholds (Casamichana et al., 2012): walking (0.1-7.0 km.h^{-1}), running at low-speed (7.1-13.0 km.h^{-1}), at medium-speed (13.1-18.0 km.h^{-1}), at high-speed (18.1-21.0 km.h^{-1}), and at sprint (>21.0 km·h^{-1}). The above categories were divided in two further locomotor categories to provide an estimation of player exercise-to-rest ratios; (a) low-speed activity (0.1-7 km.h^{-1}) and (b) moderate-and-high-speed activity (>7.0 km.h^{-1}). Sprint activities were defined as at least 1-s run >21 km.h^{-1}. Repeated-sprint sequence (RSS) was defined as a minimum of two consecutive ≥1-s sprints interspersed with a maximum of 60-s of recovery.

Exercise intensity

Match exercise intensity was quantified by monitoring heart rate (HR) during each game. HR was continuously measured with short-range telemetry (SPI-Pro-X, GPSports, Australia) and was expressed in relation to the individual maximal HR (HR_{max}) obtained throughout an incremental field test (Krustrup et al., 2003) (the highest 5-s average recorded during the test) or during the course of the match if the HRmax was higher than the value obtained during the test.

Relationship between external and internal load measures

The performance efficiency (Eff_{index}) for the quantification of the dose-response of the match stimulus was calculated as [mean speed in m·min^{-1}/mean exercise intensity (%HR_{max})] for every entire first half (Barbero-Alvarez, Boullosa, Nakamura, Andrin, & Castagna, 2012; Suarez-Arrones et al., 2014; Suarez-Arrones, Nunez, Munguia-Izquierdo, Portillo, & Mendez-Villanueva, 2013). This index integrates mean speed (i.e. external load) with respect to the relative cardiovascular stress (i.e. internal load) during the match-play into a single parameter (Barbero-Alvarez et al., 2012).

Statistical analysis

All statistical tests were performed using the Social Sciences package (SPSS, 2010, IBM SPSS Statistics 19 Core System User's Guide; SPSS Inc., Chicago, IL). Descriptive statistics were calculated on each variable and Shapiro-Wilk test were used to verify normality. A one-way analysis of variance (ANOVA) was used to determine differences between playing positions. In the event of a significant difference, Bonferroni's post-hoc tests were used to identify any localized effects. Statistical significance was set at $P<0.05$. Data are presented as means and standard deviations (SD).

Results

Movement Analysis

The relative total distance (RTD) (±SD) covered during the half was 118.9 ± 10.7 $m \cdot min^{-1}$. As a percentage of this distance, 32.2% (38.3 ± 4.5 $m \cdot min^{-1}$) was spent walking, 38.4% (45.7 ± 6.7 $m \cdot min^{-1}$) running at low-speed, 19.7% (23.4 ± 5.8 $m \cdot min^{-1}$) at medium-speed, 5.4% (6.4 ± 2.1 $m \cdot min^{-1}$) at high-speed and 4.2% (5.0 ± 2.5 $m \cdot min^{-1}$) at sprint. Player's work-to-rest ratio was 2.1:1. Match running profiles are shown in Table 1. Playing position significantly impacted on distance covered during the half (45-min) and on work-to-rest ratio. Defenders covered the lowest RTD. Centre-Backs (CB) covered a >18 $km.h^{-1}$ distance significantly shorter than any other group. Conversely, Second-Strikers (2^{nd}S) and Wide-Midfielders (W-MD) covered the greatest RTD. W-MD covered a >18 $km.h^{-1}$ and >21 $km.h^{-1}$ distance significantly greater than any other group. Defenders presented the lowest work-to-rest ratio values. CB showed a significantly smaller work-to-rest ratio than any other group, whereas Strikers (S) did not show significantly greater values than defenders.

The number of sprints, average sprint distance and maximal sprint distance during the half (45-min) were: 12.7 ± 6.1 sprints, 18.2 ± 3.4 m, and 35.1 ±11.3 m, respectively. Sprint duration was 2.50 ± 0.5 s with one sprint being performed on average every 4.1 ± 2.4 min and the number of RSS during the half (45-min) was 3.1 ± 2.9. Playing position significantly impacted on all sprinting performance results, except in average sprint distance and time of sprint. The number of sprints and RSS recorded by the W-MD and S were significantly greater than any other group. The maximal sprint distance and average minutes between sprints recorded by the W-MD were significantly greater and smaller, respectively, than any other group, except the S (Table 2).

Exercise intensity

The average HR recorded during the half was 87.1% HR_{max} with significant differences between playing positions. W-MD recorded a significantly smaller average HR than any other group (Figure 1).

Relationship between external and internal load measures

The eff_{index} value was 1.4 with significant differences between playing positions. CB showed a significantly smaller Eff_{index} value than any other group. Conversely, W-MD showed a significantly greater Eff_{index} value than any other group, except the 2^{nd}S (Figure 1).

Table 1. **Match running profile (only first half) in professional soccer players (n = 348). Data are mean ± SD.**

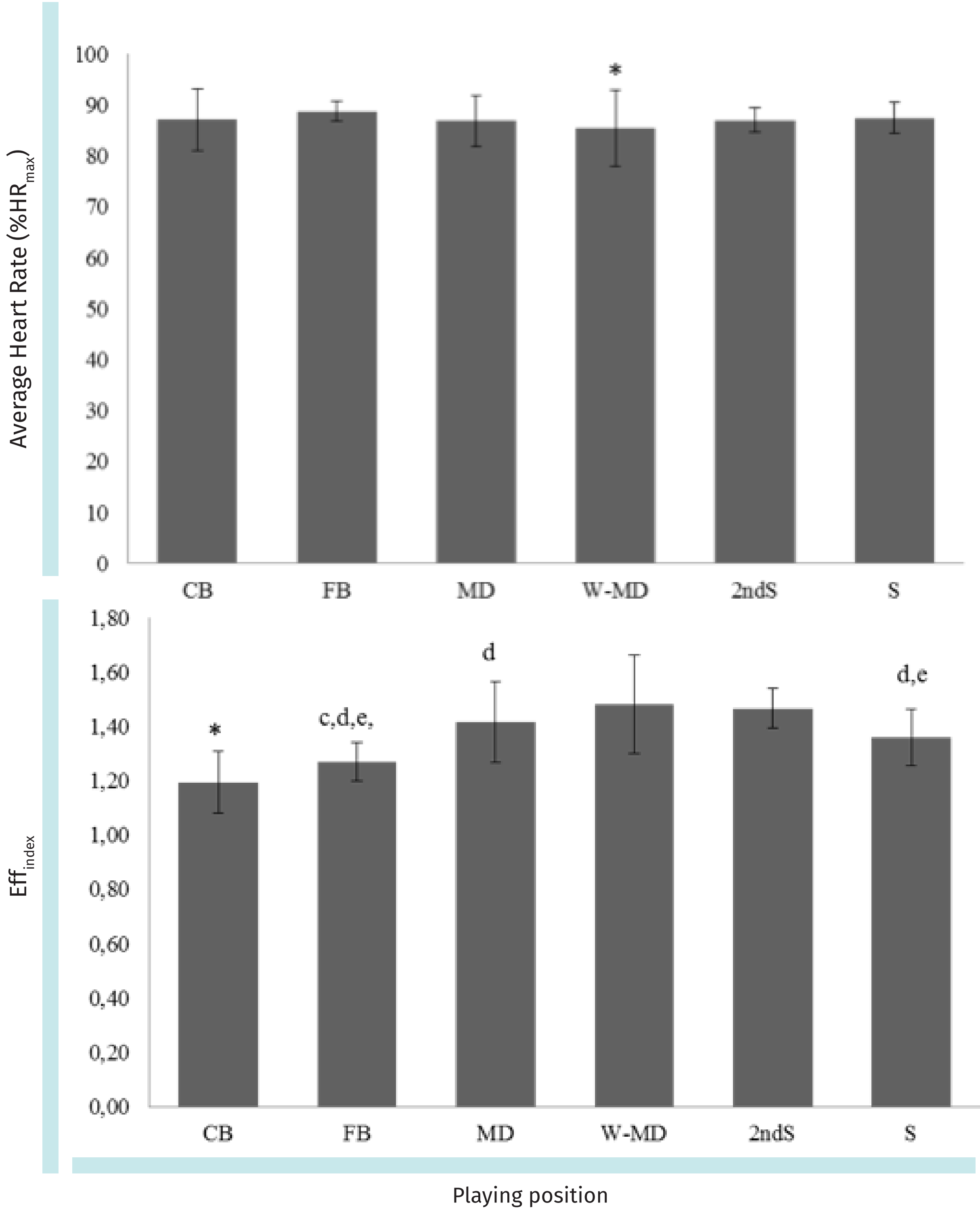
Variables	CB (n = 53)	FB (n = 57)	MD (n = 79)	W-MD (n = 68)	2nd S (n = 44)	S (n = 47)
Relative total distance ($m \cdot min^{-1}$)	103.7 ± 7.3*	112.8 ± 6.7^{c,d,e,f}	122.6 ± 6.8^{e}	125.6 ± 6.9	127.7 ± 6.8	119.1 ± 8.7^{d,e}
RD: 0.1 - 7.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	40.7 ± 3.3	39.3 ± 4.2	36.8 ± 2.9^{a,b,f}	36.3 ± 3.1^{a,b,f}	36.8 ± 4.2^{a,b,f}	41.0 ± 5.7
RD: 7.1 - 13.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	38.2 ± 4.7^{b,c,d,e,f}	43.6 ± 4.9^{c,d,e}	50.0 ± 5.8	47.6 ± 4.4	48.2 ± 5.3	43.9 ± 7.8^{c,d,e}
RD:13.1 - 18.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	17.1 ± 3.2^{b,d,e,f}	19.8 ± 3.7^{c,d,e}	26.2 ± 4.8^{e}	25.8 ± 3.9^{e}	29.7 ± 3.5	20.9 ± 4.6^{c,d,e}
RD:18.1 - 21.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	4.4 ± 1.4^{b,d,e,f}	5.4 ± 1.6^{d,e,f}	6.0 ± 1.9^{d,e}	8.1 ± 1.6	7.9 ± 1.8	6.5 ± 1.4^{d,e}
RD: >21.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	3.3 ± 1.9^{b,d,e,f}	4.6 ± 2.2^{d,f}	3.4 ± 1.7^{b,d,e,f}	7.6 ± 2.1^{+}	5.0 ± 1.8^{d,f}	6.6 ± 1.8^{d}
RD: >13 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	24.7 ± 5.2^{b,c,d,f}	29.9 ± 6.3^{c,d,e,f}	35.6 ± 6.8^{d,e}	41.6 ± 6.3	42.6 ± 5.2	34.0 ± 6.0^{d,e}
RD: >18 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	7.6 ± 2.9*	10.0 ± 3.4^{d,e,f,}	9.4 ± 3.2^{d,e,f}	15.7 ± 3.2^{+}	12.9 ± 3.1^{d}	13.1 ± 2.7^{d}
Work-to-rest ratio (RD>7.0 $km \cdot h^{-1}$/ RD≤7.0 $km \cdot h^{-1}$)	1.56 ± 0.25 *	1.90 ± 0.36^{c,d,e}	2.34 ± 0.33^{f}	2.15 ± 0.50^{f}	2.51 ± 0.46^{f}	1.95 ± 0.49

CB: Centre Backs; FB: Full Backs; **MD:** Midfielders; **W-MD:** Wide Midfielders; **2ndS:** Second Strikers; **S:** Strikers. **RD:** Relative distance.
a: Significant difference vs. CB; **b:** Significant difference vs. FB; **c:** Significant difference vs. MD; **d:** Significant difference vs. W-MD; **e:** Significant difference vs. 2ndS; **f:** Significant difference vs. S;
*: Significantly smaller than any other group; +: Significantly greater than any other group.

Table 2. Sprinting performance results obtained during matches (only firs half) in professional soccer players (n = 348). Data are mean ± SD

Variables	CB (n = 53)	FB (n = 57)	MD (n = 79)	W-MD (n = 68)	2^{nd} S (n = 44)	S (n = 47)
Number of Sprints	7.9 ± 3.9^{b,d,e,f}	11.3 ± 4.8^{d,f}	8.9 ± 4.4^{b,d,e,f}	18.7 ± 5.2	13.2 ± 4.5^{d,f}	16.6 ± 4.7
Average time of sprint (s)	2.5 ± 0.7	2.5 ± 0.5	2.4 ± 0.5	2.6 ± 0.3	2.4 ± 0.5	2.5 ± 0.3
Average minutes between sprint	5.7 ± 2.8^{b,d,e,f}	4.4 ± 2.7^{d,f}	5.4 ± 2.7^{d,e,f}	2.5 ± 0.9	3.7 ± 1.5^{d}	2.8 ± 0.8
Average Sprint Distance	18.4 ± 4.3	18.7 ± 3.8	17.6 ± 3.4	18.6 ± 2.7	17.6 ± 3.4	18.2 ± 2.7
Maximal Sprint Distance	31.8 ± 12.7^{d,f}	34.6 ± 10.2^{d}	31.1 ± 10.6^{d,f}	41.0 ± 10.0	34.0 ± 10.2^{d}	38.8 ± 10.8
Maximal Speed	27.9 ± 2.7^{b,d,f}	29.3 ± 1.8	27.7 ± 2.4^{b,d,f}	31.0 ± 2.8	28.5 ± 2.1^{d,f}	30.1 ± 2.3
RSS	1.0 ± 1.7^{b,d,e,f}	2.5 ± 2.2^{d,f}	1.7 ± 1.7^{d,e,f}	5.8 ± 3.2	3.2 ± 2.5^{d,f}	4.8 ± 2.8

CB: Centre Backs; **FB:** Full Backs; MD: Midfielders; **W-MD:** Wide Midfielders; **2^{nd}S:** Second Strikers; **S:** Strikers. **RSS:** Repeated-sprint sequence. **a:** Significant difference vs. CB; **b:** Significant difference vs. FB; **c:** Significant difference vs. MD; **d:** Significant difference vs. W-MD; **e:** Significant difference vs. 2^{nd}S; **f:** Significant difference vs. S.



CB: Centre Backs; FB: Full Backs; **MD:** Midfielders; **W-MD:** Wide Midfielders; **2ndS:** Second Strikers; **S:** Strikers. **a:** Significant difference vs. CB; **b:** Significant difference vs. FB; **c:** Significant difference vs. MD; **d:** Significant differencevs. W-MD; **e:** Significant difference vs. 2ndS; **f:** Significant difference vs. S; *: Significantly smaller than any other group.

Figura 1. **Average Heart Rate expressed in relation to the individual maximal HR (HR_{max}) and Eff_{index} during the half in professional soccer players (n = 348). Data are mean ± SD.**

Discussion

The aim of this study was to quantify for the first time the physical and physiological profile of elite professional soccer players in official games using GPS and heart rate response. The main findings of the present study reflected that 1) playing position impacted significantly on relative distance covered, work-to-rest ratio, sprinting performance results and average HR, and 2) relationships between external and internal load measures among position-specific players indicated that those with less overall running performance during match-play showed the worst results in Eff_{index}.

The overall running-patterns (119 m·min^{-1}) and sprinting performance results in the present study were higher than those previously reported in semi-professional soccer players (Casamichana et al., 2012) (113 m·min^{-1}), Australian soccer players (Varley, Gabbett, & Aughey, 2013) (104 m·min^{-1}) and youth soccer players (Buchheit et al., 2010a) (ranging from 93.5 to 108.8 m·min^{-1}), indicating that elite European professional soccer official games are played at higher relative running demands. The work-to-rest ratio values (2.1:1) in the present study were smaller than those reported in semi-professional soccer players (Casamichana et al., 2012) (2.4:1). These data suggest that higher playing standards in soccer might be associated with overall increased running demands and sprinting performance. However, comparisons should be made with caution because different GPS systems [10-Hz (Casamichana et al., 2012), 5-Hz (Varley et al., 2013) and 1-Hz (Buchheit et al., 2010a)] and time-motion analysis methods were employed (0.1-7 km.h^{-1} for rest in the present study vs. 0.1-4 km.h^{-1} in semi-professional soccer players), and previous studies revealed rather large between-system differences in the determination of distance covered (Li et al., 2012; Randers et al., 2010). Nevertheless, the present study reflects the specific demands during match-play (official games) in professional soccer players using GPS devices, and can be used to develop position-specific training tasks based on this tactical formation. Also, the work-to-rest ratio obtained can also help coaches to plan specific intermittent exercise training protocols.

Defenders presented the lowest values of RTD and work-to-rest ratio. CB showed the lowest values of distance at high-speed, work-to-rest ratio and Eff_{index}, while 2ndS and W-MD presented the highest values of RTD and effindex. W-MD was the playing position with significantly lowest average HR, highest high-speed running and sprinting values. Probably, the wide differences between CB and W-MD observed in the current study could be related to the tactical roles and training adaptations. W-MD have a linking role in the team and need to complete fast movement away from defending players, take advantage on goal scoring opportunities (Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009) and also back to defend when their team lose the ball. While the average sprint distance was similar for all specific positions (~18 m), with this tactical formation and game philosophy W-MD presented the highest values in maximal sprint distance and the highest number of RSS (41 m and 6 RSS during the half, respectively), excluding the S who reported similar values (39 m and 5 RSS during the half, respectively). Specific positions showed maximal sprint distance from 32 to 41 m with averages of peaks of speed from 28 to 31 $km \cdot h^{-1}$. A previous study reported as a rule, speed sessions typically conducted by fitness trainers include short sprints (< 20 m) (Mendez-Villanueva, Buchheit, Simpson, Peltola, & Bourdon, 2011). Therefore, this information should be used for the prescription of drills that replicate game repeated-sprint sequences, sprint distances and peaks of speed, in order to prescribe specific trainings adapted to individual game demands; and the assessment of running speed in developing players should therefore include assessment of both acceleration and distances ~40 m (Mendez-Villanueva et al., 2011).

Our results confirm data on position-specific running patterns reported in adult soccer players using video-analysis (Di Salvo et al., 2007; Di Salvo, Pigozzi, Gonzalez-Haro, Laughlin, & De Witt, 2013) or in youth soccer players (Buchheit, Mendez-villanueva, Simpson, & Bourdon, 2010b). Therefore, this information reflects that players have specific demands during match-play and can be used to develop position-specific training strategies. Moreover, the Eff_{index} expressed how efficiently one can run with a given cardiovascular stress (Barbero-Alvarez et al., 2012). Accordingly, the relationships between external and internal load measures among position-specific in the present study indicates that players with less overall running performance during match-play were the worst in Eff_{index}.

Conclusion

The assessment of the external (i.e., running demands using GPS devices) and internal (i.e., HR responses) load imposed during the competition is the first step preceding the design of position-specific conditioning training tasks controlled with this technology. This study has quantified physical and physiological demands of professional soccer players with GPS and HR response and has verified a number of statistically significant differences between the different playing positions. Coaches should be focused on the specific physical and physiological requirements of the playing positions to optimize the training prescription in soccer. Future studies in professional soccer players adding physical performance assessments and using relative intensity zones during official games are needed.

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CAPÍTULO 3. ARTÍCULO 2

(CHAPTER 3. STUDY 2)

"En el fútbol todo se complica por la presencia del rival"

JEAN PAUL SARTRE

Relationship between external and internal loads of professional soccer players during full matches in official games using global positioning systems and heart-rate technology

Abstract

Purpose: To analyze the match running profile, distance travelled over successive 15 minutes of match-play, heart rates and effindex of professional soccer players with Global Positioning System (GPS) and heart rate (HR) in official competition. **Methods:** Twenty-six professional players were investigated during full-matches in competitive club level matches (n=223). Time-motion data and HR were collected using GPS and HR technology. **Results:** The relative total distance was 113±11 m·min^{-1} with substantial differences between halves. For all the playing positions, a substantial decrease in total distance and distance covered >13.0 km·h^{-1} was observed in the second half in comparison with the first. The decrease during the second half in distance covered >13.0 km·h^{-1} was substantially higher than in total distance. The average HR recorded was 86.0% HR_{max} and the relationship between external and internal load value (Eff_{index}) was 1.3, with substantial differences between halves in all playing positions, except strikers for Eff_{index}. Wide-midfielders reflected substantially the lowest mean HR and highest Eff_{index}, while CB showed substantially the lowest Eff_{index} than any other playing position. **Conclusion:** The current study confirmed the decrement in player´s performance toward the end of match in all playing positions. Wide-midfielders performed the highest and fittest levels of physical and physiological demands, respectively, whereas centre-backs performed the lowest and unfittest levels of physical and physiological demands, respectively. The relationship between external and internal load measures among position-specific confirms that players with more overall running performance during the full-match were the best in Eff_{index}.

Keywords: team sport, time motion, football, heart rate

Introduction

Time-motion analysis, or player tracking, is commonly used by scientists to evaluate the performance (Rampinini, Impellizzeri, Castagna, Coutts, & Wisloff, 2009) and understand the training demands in team sports. A range of methods can be used to track and monitor players activity profile and load during competitive games and training. Microtechnology devices that include global positioning systems (GPS) and other movement sensors is now widely used in practice in many sports to assess the external load for players as it has been shown to provide a reliable and valid measure of the physical activity profile of team sports (Coutts & Duffield, 2010). The internal load of players is commonly monitored using physiological and /or perceptual measures such as heart rate and rating of perceived exertion (Coutts & Cormack, 2014). By describing the changes in relationships between internal and external loads during competition and training, it may be possible to understand the changes of player performance or fitness status. Few studies have examined both the internal and external loads of team sport players during competition and training (Kempton, Sirotic, & Coutts, 2015; Suarez-Arrones, Arenas, et al., 2014; Suarez-Arrones et al., 2015).

Different technologies are used to monitor player activity profiles (i.e. external loads) in training and competition, with GPS technology often used to monitor training whilst multiple camera semi-automatic systems in competition (Buchheit et al., 2014). Limited research within soccer may possibly be attributed to the Federation International of Football Association not permitting the use of GPS within professional competition matches. Therefore, whilst there have been many published reports of training activity profiles in soccer (Casamichana, Castellano, & Castagna, 2012) there is relatively little information on player activity profiles during competition with GPS devices (Duffield, Coutts, McCall, & Burgess, 2013; Suarez-Arrones et al., 2015; Varley & Aughey, 2013). Most reports from top level soccer players have been derived from multiple camera semi-automatic systems (Bradley et al., 2009; Di Salvo et al., 2007; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). The major benefit of GPS and HR technology within competition settings is the ability to provide real-time movement demand (e.g. distance and speed) and internal load (HR) information of on-field players to coaches, and compare easily the training drills data with the data from football matches using the same technology. The video footage cannot provide internal load information. In competition settings, the video footage is a time consuming process, which needs to take place for each individual player, making it impossible to provide real-time movement demand information. Additionally, GPS technology allows for further analysis of speed. A detailed understanding of match demands enables for the provision of individually tailored training programs that more accurately reflect competition demands and ensures players reach optimal training targets.

In an effort to better understand the demands of soccer in official games studies using multiple camera systems have described the overall activity profiles and temporal changes in activity completed in different speed zones during match play (Bradley et al., 2009; Di Salvo et al., 2007; Di Salvo et al., 2009; Rampinini et al., 2007). Although some studies have reported no differences between halves (Di Salvo et al., 2007; Varley, Gabbett, & Aughey, 2013), most studies reported a decline in the total distances covered and high intensity running in the second half compared to the first half (Bradley et al., 2009; Di Salvo et al., 2009; Mohr, Krustrup, & Bangsbo, 2003; Rampinini et al., 2007). Similarly, temporal reductions in the total distance and distances covered at higher speeds running distances in 15-minutes periods of match play have been reported independent of the player position (Bradley et al., 2009; Mohr et al., 2003; Mohr, Krustrup, & Bangsbo, 2005). These changes in activity profile have been reported to be due to a combination of decrement of player performance and tactical adjustments. However, many of these studies are limited as it is difficult to clearly identify the decrement of player performance in the absence of internal load information.

Only one study (Suarez-Arrones et al., 2015) has described the physical activity profiles of top professional soccer players during official competitions using GPS technology. Moreover, no data is currently available about the internal and external loads of professional soccer players during a full-match in official games. The aim of this paper is to examine the temporal changes (i.e. 15 min periods) in the internal and external loads of top professional soccer players during match play. External (i.e. distances travelled in various speed zones), internal (heart rate) and integrated measures of load (i.e. the Eff_{index}) of the various playing positions during official competitions accounting for will be described. Based on previous literature, our working hypothesis was the decrement on players performance toward the end of match (Bradley et al., 2009; Mohr et al., 2003, 2005). We also hypothesized that the highest loads would be observed in wide-midfielders, while central defenders would show the lowest loads (Bradley et al., 2009; Di Salvo et al., 2007; Di Salvo et al., 2009; Varley et al., 2013).

Methods

Subjects

Twenty six professional outfield players (27.3 ± 3.4 years, 180.4 ± 3.6 cm, 76.2 ± 6.8 kg) from the same team were investigated during competitive club level matches in the national league, national cup, national super cup and UEFA Europa League. All the players participated on average in ~ 14 h of combined soccer (4-6 sessions), strength (1-2 sessions), specific training (1 session) and competitive play (1-2 games per week) per week. All players were well accustomed to this training and competition load. Written informed consent was obtained from players before the investigation. The experimental protocol was approved by the Institutional Ethics Committee University of Pablo de Olavide.

Experimental procedures

An observational design was used to examine the internal and external loads of soccer players during competitive matches using GPS technology and HR response. Match analyses were performed 3–15 times on each player over a period of two seasons (n = 223 match files). The high level of the opposing teams and in keeping the competition in format consistent, match-by-match variability in running performance was likely reduced (Rampinini et al., 2007). All matches were performed on outdoor natural grass fields using 11 players per side. Tactically, the team used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a "second striker". Since players' roles within the team structure changed little during the games analysed, all players were assigned to 1 of 6 positional groups; centre-backs (CB, n = 44 files), fullbacks (FB, n = 47 files), midfielders (MD, n = 54 files), wide midfielders (W-MD, n = 26 files), second strikers (2^{nd} S, n = 20 files) and strikers (S, n = 31 files). Playing time was 2 x 45 min and only time-motion data of players who participated in the entire game were included for the subsequent analyses.

Activity pattern measurements

The players were required to wear a GPS unit (SPI Pro X; GPSports Systems, Canberra, Australia) during the game, which was fitted to the upper back (i.e., between the shoulder blades) of each player using an adjustable neoprene harness. The data stored includes HR, time, speed, and distance. GPS data were recorded at 5 Hz frequency and accelerometer data to 100 Hz respectively. The validity and reliability of the GPS system have been previously reported (Coutts & Duffield, 2010; Varley, Fairweather, & Aughey, 2012) and used in soccer players (Buchheit, Simpson, & Mendez-Villanueva, 2013; Buchheit, Spencer, & Ahmaidi, 2010; Casamichana et al., 2012; Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013; Suarez-Arrones et al., 2015). The current system has been reported to be capable of measuring individual movement patterns in soccer (Randers et al., 2010). To remove as much associated error as possible, researchers used the same devices on the same individuals when monitoring soccer players. None of the soccer fields used caused interferences in GPS signal.

Match running demands analysis

Time-motion data from all players were analysed with the software designed (Team AMS-R1-2012-3; GPSports Systems, Canberra, Australia) to provide objective measures of physical match performance (n = 223 files from 26 different players). The players' activities ranges selected were adapted from previous studies with professional soccer players using GPS technology (Suarez-Arrones, Torreno, et al., 2014) as follows: 1) total distance covered (TD), 2) distance covered running above moderate-speed (>13.0 $km \cdot h^{-1}$) and 3) above high-speed (>18.0 $km \cdot h^{-1}$). For every 15-min period, calculations were made of relative total distance travelled throughout the match.

Exercise intensity

Match internal exercise intensity was quantified by monitoring heart rate (HR) during each game. Heart rate was continuously measured with HR belts (Polar®, Finland) attached to their chest and was expressed in relation to the individual maximal HR (%HR_{max}). The individual maximal HR was obtained throughout the latest yo-yo intermittent recovery test (Krustrup et al., 2003) regularly assessed during the season, or during the course of the match if the HR_{max} was higher than the value obtained from the field test.

Relationship between external and internal load measures

The performance efficiency (Eff_{index}) for the quantification of the dose-response of the match stimulus was calculated as [velocity in $m \cdot min^{-1}$/%HR_{max}] for every entire the match (Suarez-Arrones, Torreno, et al., 2014). This index integrates mean speed (i.e. external load) with respect to the relative cardiovascular stress (i.e. internal load) during the match-play into a single parameter (Barbero-Alvarez, Boullosa, Nakamura, Andrin, & Castagna, 2012) and express during a determined period (e.g., 45 minutes) how efficiently one can run with a given cardiovascular stress. The Eff_{index} has shown to be an appropriate tool for detecting differences on physical profile of elite professional soccer players of different playing position during official games (Suarez-Arrones et al., 2015) and changes on athletes performance over the entire match (Barbero-Alvarez et al., 2012).

Statistical analysis

Variables are reported as mean ± standard deviation (SD). All variables presented normal distribution (Shapiro-Wilk Test). The differences between the first and second halves of the match were determined using a Student's dependent t-test for paired samples (confidence interval, [CL], 90%). A repeated-measures analysis of variance was used to determine differences in the distance covered in each speed zone and during each successive 15-min period of match-play. Significant differences were determined by a Bonferroni's post-hoc test. Cohen's effect size (ES) was also calculated using the Hopkins' spreadsheets (W. G. Hopkins, 2006, 2007) to compare the magnitude of the differences between groups on certain variables (Cohen, 1988) and quantitative differences were assessed qualitatively (W.G. Hopkins, Marshall, Batterham, & Hanin, 2009) as: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, probably; 95–99%, very likely; and >99%, almost certain. A substantial effect was set at >75% (Batterham & Hopkins, 2006; Suarez-Arrones, Arenas, et al., 2013; Suarez-Arrones, Nunez, Munguia-Izquierdo, Portillo, & Mendez-Villanueva, 2013). If the chance of higher or lower differences was >75%, the true difference was assessed as clear (substantial). The SPSS statistical software package (V20.0 for Windows, SPSS Inc., Chicago, IL) was used for data analysis.

Results

Movement Analysis

The relative total distance (TD) (±SD) covered during the match was 112.9 ±10.6 $m\cdot min^{-1}$ with substantial differences between first and second half (117.0 ±10.4 $m\cdot min^{-1}$ vs. 108.8 ±10.7 $m\cdot min^{-1}$, respectively). As a percentage of this distance, 28% (31.3 ±8.0 $m\cdot min^{-1}$) was running above medium-speed (>13.0 $km\cdot h^{-1}$) with substantial differences between first and second half (33.4 ±8.2 $m\cdot min^{-1}$ vs. 29.3 ±7.7 $m\cdot min^{-1}$, respectively), and 9.0% (10.0 ±3.7 m·min^{-1}) above high-speed (>18.0 km·h^{-1}) also with substantial differences between first and second half (10.7 ±3.9 m·min^{-1} vs. 9.4 ±3.5 m·min^{-1}, respectively). Differences between the first and second halves for intensity and load each specific playing position are shown in Table 1 and Figure 1, respectively. All playing positions demonstrated a substantial decrease in TD and distance covered >13.0 km·h^{-1} in the second half compared with the first (Table 1 and Figure 1). Nevertheless, the distance travelled above high-speed (>18.0 km·h^{-1}) was substantially reduced during the second half only in FB, MD and S (Table 1 and Figure 1). The decrease during the second half in distance covered >13.0 km·h^{-1} was substantially higher than in TD (-10.9% vs. -6.9%, respectively).

Playing position significantly impacted on distance covered during the match (Table 1). Defenders covered the lowest TD, while W-MD and 2ndS covered the highest TD. MD covered a substantially greater TD than S during the first half, but not during the second. Defenders covered substantially lower distance >13 km·h^{-1}, while W-MD and 2ndS travelled substantially the higher distance >13 km·h^{-1} during the first half. The W-MD also travelled greater distance >13 km·h^{-1} during the second half but the 2ndS substantially reduced the distance travelled in this speed zone during this period. MD covered a substantially greater distance >13 km·h^{-1} than S during the first half, but not during the second. CB covered substantially the lowest distance >18 km·h^{-1}, while W-MD travelled the greatest distance. FB and MD covered substantially lower distance >18 km·h^{-1} than S and 2ndS (Table 1).

Analysis of the distance travelled over successive 15 min periods of match-play are shown in Table 2. The data revealed for all the playing positions a greater distance covered during the first 15 min compared with other periods of the match, with less distance travelled during the last 15 min compared with the periods of 0–60 min for CB, FB, MD, S, and with the periods of 0–75 min for W-MD and 2ndS (Table 2).

Internal exercise intensity

The mean HR during the match was 86.0 ±4.9 %HR_{max} with substantial differences between first and second half (87.0 ±5.2 %HR_{max} vs. 85.0 ±4.6 %HR_{max}, respectively). Differences in heart rate response between halves for each specific playing position are shown in Table 1. During the second half FB, 2ndS and S substantially reduced their HR in comparison with the first half, whereas the mean HR in CB, MD and W-MD remained stable throughout the whole match with no differences between halves (Table 3).

The HR responses of the various playing positions are shown in Table 3. Mean HR was lower in W-MD than any other playing position. During the first half, mean HR was substantially lower in the 2^{nd}S than FB and S; and in MD than FB. During the second half, mean HR was lower in 2^{nd}S compared to the CB, FB and MD; and in S than FB and MD.

Relationship between external and internal load measures

The effindex during the match was 1.3 ±0.2 with substantial differences between first and second half (1.4 ±0.2 vs. 1.3 ±0.2, respectively). Differences between halves for each specific playing position are shown in Table 1. The Eff_{index} was substantially reduced during the second half compared with the first in all the playing positions, with the exception of S in which there were no differences (Table 3).

Differences in Eff_{index} between specific positions are shown in Table 1. W-MD had the substantially highest Eff_{index}, while CB showed substantially the lowest. In addition, 2^{nd}S presented substantially higher Eff_{index} than FB, MD and S, like S in regard to FB. The Eff_{index} in MD was substantially higher than FB and S during the first half, but only in respect FB during the second half (Table 3).

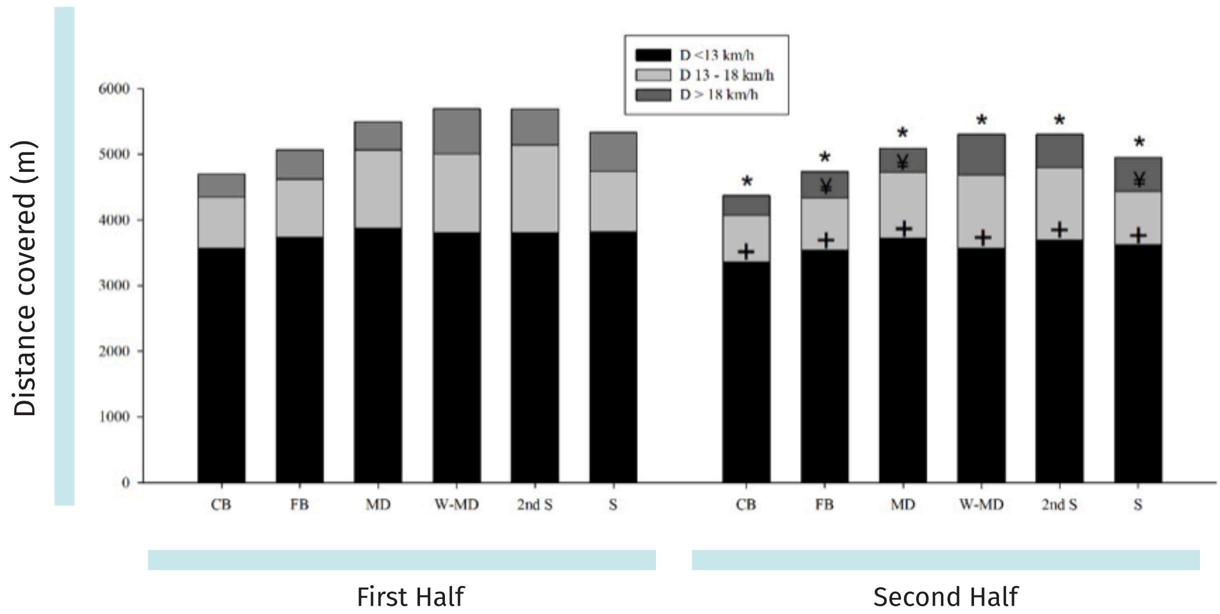

Figure 1. Match running profile in professional soccer players (n = 223). D: Distance covered. *Substantial difference in total D vs first half; +Substantial difference in D >13 km·h^{-1} vs first half; ¥Substantial difference in D >18 km·h^{-1} vs first half.

Table 1. Match physical activity profile in professional soccer players (n = 223, all data are mean ± SD).

	Total distance covered (m.min^{-1})		Distance covered >13 km.h^{-1} (m.min^{-1})		Distance covered >18 km.h^{-1} (m.min^{-1})	
Position	1st half	2nd half	1st half	2nd half	1st half	2nd half
CB (n=45)	105 ±8 $^{+}$	*97 ±10 $^{+}$	25 ±6 $^{+}$	*23 ±5 $^{+}$	8 ±3 $^{+}$	7 ±2 $^{+}$
FB (n=47)	113 ±7 ^{c,d,e,f}	*105 ±8 ^{c,d,e,f}	30 ±6 ^{c,d,e,f}	* 27 ±7 ^{c,d,e,f}	10 ±3 ^{d,e,f}	*9 ±3 ^{d,e,f}
MD (n=54)	122 ±6 ^{d,e}	*113 ±6 ^{d,e}	36 ±7 ^{d,e}	*30 ±6 ^{d,e}	10 ±3 ^{d,e,f}	*8 ±3 ^{d,e,f}
W-MD (n=26)	127 ±5	*118 ±6	42 ±5	*39 ±5	15 ±3	14 ±2
2nd S (n=20)	127 ±6	*118 ±6	42 ±4	*36 ±5 ^{d}	12 ±2 ^{d}	11 ±3 ^{d}
S (n=31)	119 ± 9^{c,d,e}	*110 ±10 ^{d,e}	34 ±6 ^{c,d,e}	*29 ±6 ^{d,e}	13 ±3 ^{d}	*11 ±3 ^{d}

CB: Centre Backs; **FB:** Full Backs; MD: Midfielders; **W-MD:** Wide Midfielders; **2ndS:** Second Strikers; **S:** Strikers.
a: Substantial difference vs. CB; **b:** Substantial difference vs. FB; **c:** Substantial difference vs. MD; **d:** Substantial difference vs. W-MD; **e:** Substantial difference vs. 2ndS; **f:** Substantial difference vs. S; *: Substantially smaller than first half; +: Substantial difference than any other specific positions.

Table 2. Relative distance travelled over successive 15 min periods of match-play in professional soccer players (n = 223, all mean ± SD).

	Relative distance covered ($m.min^{-1}$): Periods of the 1st Half			Relative distance covered ($m.min^{-1}$): Periods of the 2nd Half		
Position	0 - 15 min[a]	15 - 30 min[b]	30 - 45 min[c]	45 - 60 min[d]	60 - 75 min[e]	75 - 90 min[f]
CB (n=45)	110 ±9	101 ±9 [a]	102 ±10 [a]	98 ±18 [a]	96 ±18 [a,c]	95 ±17 [a,b,c,d]
FB (n=47)	119 ±7	110 ±11 [a]	109 ±10 [a]	109 ±10 [a]	105 ±10 [a,b,c,d]	102 ±11 [a,b,c,d]
MD (n=54)	129 ±9	118 ±8 [a]	120 ±11 [a]	120 ±10 [a]	110 ±9 [a,b,c,d]	109 ±9 [a,b,c,d]
W-MD (n=26)	133 ±8	124 ±9 [a]	122 ±10 [a]	125 ±8 [a]	118 ±11 [a,b,c,d]	110 ±13 [a,b,c,d,e]
2nd S (n=20)	136 ±10	124 ±8 [a]	119 ±14 [a,b,d]	127 ±9 [a]	115 ±7 [a,b,d]	111 ±11 [a,b,c,d,e]
S (n=31)	126 ±10	115 ±12 [a]	117 ±10 [a]	115 ±13 [a]	108 ±12 [a,b,c,d]	107 ±12 [a,b,c,d]

CB: Centre Backs; **FB:** Full Backs; **MD:** Midfielders; **W-MD:** Wide Midfielders; **2ndS:** Second Strikers; **S:** Strikers.

a: Substantial difference vs. 0-15 min period; **b:** Substantial difference vs. 15-30 min period; **c:** Substantial difference vs. 30-45 min period; **d:** Substantial difference vs. 45-60 min period; **e:** Substantial difference vs. 60-75 min period.

Table 3. Mean heart rate (%HR_{max}) and Eff_{index} in professional soccer players (n = 223, mean ± SD).

	Heart Rate (%HR_{max})		Eff_{index} (arbitrary units)	
Position	1st half	2nd half	1st half	2nd half
CB (n=45)	88 ±6	86 ±5	1.20 ±0.1	*1.14 ±0.1
FB (n=47)	89 ±2	*87 ±2	1.27 ±0.1 [a]	*1.21 ±0.1 [a]
MD (n=54)	87 ±6 [b]	86 ±3	1.42 ±0.2 [a,b,f]	*1.32 ±0.1 [a,b]
W-MD (n=26)	83 ±8 [+]	81 ±6 [+]	1.53 ±0.2 [+]	*1.46 ±0.2 [+]
2nd S (n=20)	87 ±2 [b,f]	*84 ±2 [a,b,c]	1.46 ±0.1 [a,b,c,f]	*1.41 ±0.1 [a,b,c,f]
S (n=31)	88 ±3	*84 ±6 [b,c,]	1.35 ±0.1 [a,b]	1.33 ±0.2 [a,b]

CB: Centre Backs; FB: Full Backs; **MD:** Midfielders; **W-MD:** Wide Midfielders; **2ndS:** Second Strikers; **S:** Strikers.
a: Substantial difference vs. CB; **b:** Substantial difference vs. FB; **c:** Substantial difference vs. MD; **d:** Substantial difference vs. W-MD; **e:** Substantial difference vs. 2ndS; **f:** Substantial difference vs. S; *: Substantially smaller than first half; +: Substantial difference than any other specific positions.

Discussion

The aim of this study was to quantify for the first time the internal and external loads of elite professional soccer players during full official matches using GPS and heart rate response. The main findings of the present study showed that 1) for all the playing positions a substantial decrease in distance covered was reflected in the second half; 2) a greater distance was covered during the first 15 min compared with other periods of the match; 3) only 2nd S and S had a substantially reduced HR during the second half (remained unchanged in others); and Eff_{index} was substantially reduced in almost all the playing positions during the second half. In addition, playing position impacted substantially on relative distance covered at different speeds, and relationships between external and internal load among position specific players showed that those with higher overall match activity profile had the highest Eff_{index}.

The relative total distances covered in the present study (~113 $m \cdot min^{-1}$) were similar than reported in semi-professional soccer players (Casamichana et al., 2012) (113 $m \cdot min^{-1}$), and higher than professional soccer players competing in the Australian League (A League) (Varley et al., 2013) (~104 $m \cdot min^{-1}$) and youth soccer players (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010) (range: 94–109 $m \cdot min^{-1}$). These results suggest that the elite European official games are played at similar mean speed as semi-professional soccer players during friendly matches (Casamichana et al., 2012). However, accurate comparison between the present and this previous study is difficult due to methodological differences as the previous study (Casamichana et al., 2012) had a small sample (i.e. 27 recordings from 7 friendly matches), and included data from players who had relatively short match times (i.e. >15 min). In contrast, in the present study, we only included player's data in the analysis if they played entire matches. Therefore, comparison of findings between these studies needs to be interpreted cautiously as it is likely the longer the match duration, the lower the match speeds. Indeed, a previous study using GPS technology showed that overall match in elite European professional soccer players are played during 45 min (only first half) at ~119 $m \cdot min^{-1}$ (Suarez-Arrones et al., 2015).

The present results also showed a decrease in both TD and distance covered >13.0 $km \cdot h^{-1}$ in the second half for all the playing positions. The decline in movement patterns between halves is probably associated to the decrement of player performance (Bangsbo, Mohr, & Krustrup, 2006; Mohr et al., 2003; Rampinini et al., 2009), although reductions in running performance also could be due to tactical demands or other match-related factors. Nonetheless, the reduced Eff_{index} supports the presence of decrement of player performance as the player's relative distances travelled compared to the internal load response was reduced, but with differing magnitudes for the different playing positions (range from -3% in 2^{nd}S to -7% in MD). The greatest decreases appeared in the distance covered >13 $km{\cdot}h^{-1}$, suggesting that decrements of distances covered at speeds above this threshold may be a more reliable indicator of decrement on performance in soccer players. Notably, however, not all of the playing positions reduced their running at high-speed during the second half. This may be a sign of 'pacing', in that players may modify their activities at lower speeds in order to preserve their capacities to exercise at higher speeds throughput the whole game (Duffield, Coutts, & Quinn, 2009; Edwards & Noakes, 2009). Indeed, it has previously been shown that the ability to main high-intensity running (>18.0 $km{\cdot}h^{-1}$) is a crucial element of soccer performance (Mohr et al., 2003) and may even be critical to the outcome of matches (Stolen, Chamari, Castagna, & Wisloff, 2005). Previous studies reflected similar differences between first and second half activity profiles in professional top-class soccer players (Mohr et al., 2003; Rampinini et al., 2009) using video analyses; and players of the English Premier League with less distance at high-intensity covered during the first half were able to travel more distance in the second half (Rampinini et al., 2007). Furthermore, it has also been shown that players with higher levels of decrement of performance have decreased involvements the ball and decrease in the total number of short passes and successful short passes during matches (Rampinini et al., 2009).

This diminution in physical activity profile as the game progresses has also been demonstrated through a substantial reduction in the relative distance covered in the last 15-min period of the match compared with the first 15 minutes (range from -14% to -18%). Similar research findings was reflected by Mohr et al. (2003) who used video match analyses to show that players from all playing positions showed a decrease in high-intensity running in 15-min intervals towards the end of the match. These authors argue that almost players in elite soccer tax the physical capacity during a game (Mohr et al., 2003). However, in the present study we observed that whilst the effindex was substantially reduced in almost all players (with the exception of S), only half of the playing positions had a reduced activity profile in the higher speed zone.

While the data of our study are novel, there are limitations that should be acknowledged. First, our sample size was relatively small, with different number of players among some playing positions, and only included data from a single team. Therefore, the results of this study may be specific to these team players and to the planning adopted by coaching staff, including a possible bias towards the tactical formation (4-4-1-1) used for the team assessed. The participating team was competing at the second highest standard of soccer competition in Europe. Consequently, further studies involving a greater number of participating teams are warranted to establish more representative results. Another limitation is that GPS has shown to be a valid method for measurement of distance travelled at low to moderate but not high speeds (Johnston et al., 2012). The reliability of GPS decreases with the increased velocity of movement. Therefore, caution must be taken when interpreting individual movement demands performed at highest velocities. An increased sample rate could improve the reliability and validity of GPS devices. Consequently, more studies with currently available GPS systems recording at increased sample rate are required to replicate our findings and improve the reliability and validity of the results. Although research has shown GPS to be a valid and reliable measure of team sport athlete movement demands in a controlled environment (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014), more studies under realistic conditions must be replicated in soccer players to support the ecological validity of GPS and HR technology in movement demands. Studies adding physical performance assessments, using relative intensity zones and analyzing high intensity running activity (accelerations, decelerations, impacts) during official games and considering tactical elements, situational and interactional contexts (i.e., game location, game result, quality of opposition) are imperative.

Practical applications and conclusions

This study confirmed the research hypothesis of decrement in players performance toward the end of game in all playing positions. It also confirmed that W-MD performed the highest physical and physiological demands, respectively, whereas CB performed the lowest physical and physiological demands, respectively. The relationship between external and internal load measures among position-specific in this study confirms that players with more overall running performance during the full-match (W-MD and 2^{nd}S) presented the higher values in Eff_{index}.

Coaches, practitioners and sports scientists working within top professional soccer players should be aware of the physical and physiological demands associated with the competition. Findings obtained from monitoring internal and external loads assessed in this study may be used to provide a stronger understanding of the specificity of training and drill design. Indeed, training activities should focus on the level of physical and physiological demands of players during the matches. Many training drills can elicit similar internal loads (HR-based) compared to actual match-play providing an optimum training physiological stress. However, these drills may elicit an inappropriate external load in comparison with the movement patterns that players perform during the match according to the specific game model. As an alternative, physical training activities can be designed to replicate the position-specific demands observed in this study. Ideally, each team should have its own physiological and mechanical demands associated to soccer match-play during official games, measured with the same technology that these players are monitored during training sessions (i.e. GPS-HR).

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CAPÍTULO 4. ARTÍCULO 3

(CHAPTER 4. STUDY 3)

"En algún lugar, algo increíble está esperando ser conocido"

CARL SAGAN

Variability of GPS-derived running performance during official matches in 15 elite professional soccer players (under review)

Abstract

Background: In this study, the between match running performance variability was assessed in soccer players. **Methods**: GPS-derived data from nineteen elite soccer players were collected over two consecutive seasons. Time-motion data for players with more than five full-match were analyzed (n=202). Total distance covered (TD), TD >13-18 km/h, TD >18-21 km/h, TD >21 km/h, number of acceleration >2.5-4 m.s^{-2} and >4 m.s^{-2} were calculated. The match-to-match variation in running activity was assessed by the typical error expressed as a coefficient of variation (CV%) and the magnitude of the CV was calculated (effect size). **Results**: When all players were pooled together, CVs ranged from 5% to 77% (first half) and from 5% to 90% (second half) for TD and number of acceleration >4 m.s^{-2} and the magnitude of the CVs were rated from small to moderate (effect size = 0.57-0.98). The CV was likely to differ between playing positions (e.g., TD > 13-18 km/h 3.4% for second strikers vs 14.2% for strikers and 14.9% for wide-defenders vs 9.7% for wide-midfielders). **Conclusions**: Present findings indicate that variability in players' running performance is high in some variables and likely position-dependent. Such variability should be taken into account when using these variables to prescribe and/or monitor training intensity/load.

Keywords: monitoring; football players, worthwhile changes, playing position

Introduction

During the past decade, match running performance monitoring has become common practice in professional soccer players (Carling, 2013). The detailed analysis of the match running activity is likely important to profile the individual physical demands, which can be used to define and prescribe tailored training sessions targeting players' game and playing position requirements (Andrzejewski, Konefał, Chmura, Kowalczuk, & Chmura, 2016; Di Salvo & Pigozzi, 1998).

Variability of the locomotor activity during matches (i.e., degree of change in a particular index when repeated on different occasions in similar conditions, as evidenced by the coefficient of variation (CV) of a measurement) is of great importance for sports scientists and coaches to avoid bias interpretation when assessing changes/differences in a game or training outcome. Half of a CV, for example, is thought to represent a minimal threshold needed to assess a meaningful difference (between-group comparisons) or change (training studies), or the so called “smallest worthwhile difference / change” (Hopkins, Hawley, & Burke, 1999).

Limited data on the match-to-match variation in physical performance in soccer exist (Gregson, Drust, Atkinson, & Salvo, 2010; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Analysing data obtained from a camera-based tracking system, a 5% CV for distances covered >14.4 km/h and 14.4% - 16% CV for distances covered >19.8 km/h have been reported (Gregson et al., 2010; Rampinini et al., 2007). Generally, training data is obtained using a global positioning system (GPS) and the interchangeability between camera-based and GPS is somewhat difficult as these systems are likely to provide different data for the same variables making the comparison of the physical performance obtained from the matches and trainings difficult (Buchheit, Allen, et al., 2014). A logical consensus in sport science is that the most effective training for preparing players for competition is to closely replicate and overload the competitive performance requirements/demands. Therefore, training prescriptions in soccer should take into account the players’ game demands for the different playing position (Di Salvo & Pigozzi, 1998). Therefore, assessing the variability of the running performance from GPS-derived data in professional soccer players during official games would be of great interest to compare and interpret the data arising from soccer training in comparison with game demands.

Despite the growing use of GPS devices in elite football, and the statement of the FIFA® allowing the use of this technology during the official matches, to date no match-to-match variability on running performance during official games is available. Therefore, the aim of this study was to assess the match-to-match variability obtained using GPS devices, collected during official games in professional soccer players.

Materials and methods

Participants

Time-motion analysis of running activity was collected in 19 professional soccer players (age: 27.1 ± 3.3 yrs; height: 180.7 ± 3.2 cm and body mass: 76.0 ± 6.6 kg). All the players participated on average in ~ 14h of combined soccer (4-6 sessions), strength (1-2 sessions), specific training (1 session) and competitive play (1-2 games per week) per week. The players gave a written informed consent. The experimental protocol was approved by the local Institutional Ethics Committee of the University of Pablo de Olavide (Master de Fútbol, Research Department), and have been conducted according to the principles expressed in the Declaration of Helsinki.

Design

An observational design was used to examine the physical demands and exercise intensity in male soccer players during competitive matches using GPS technology. Nineteen outfield players from the same team were investigated during competitive club level matches in the national league, national cup, national super cup and UEFA Europa League. Match analyses were performed 5-28 times on each player over a period of two seasons (n = 202). All matches were performed on outdoor natural grass fields using 11 players per side. Tactically, the team used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a "second striker". Since players' roles within the team structure changed little during the analyzed games, all players were assigned to 1 of 6 positional groups: central-defender (3 players, 38 files with 13, 7, and 18 files for the three different players, respectively), wide-defender (5 players, 47 files with 14, 14, 6, 7 and 6 files for the different 5 players, respectively), central-midfielder (3 players, 50 files with 16, 28 and 6 files for the three different players, respectively), wide-midfielders (3 players, 23 files with 8, 5 and 10 files for the three different players, respectively), second strikers (2 players, 17 files with 5 and 12 files for the two different players, respectively) and strikers (3 players, 27 files with 5,17 and 5 files for the three different players, respectively). Only data from players with full-match data set were analyzed. Playing time was 2 x 45 min plus additional time. The data from each half were re-calculated to 45 min to avoid discrepancies in the playing time due to different additional time.

Activity pattern measurements

During each match a global positioning system unit (SPI Pro X, GPSports, Canberra, Australia) recording at 5 Hz (interpolated to 15 Hz) was fitted to the upper back of each player using an adjustable neoprene harness. A good accuracy was reported for the assessment of total distance (typical error of the estimate; TEE: 0.4-3.7%), a slightly higher CV for high speed running distance (7.5%) and a higher CV for very high speed running (23.2%) (Scott, Scott, & Kelly, 2016). The measure of peak speed presented a relatively low TEE (3.3%) and very high intraclass correlation coefficient (r = 0.92) (Buchheit, Allen, et al., 2014). A TEE of 3.7% and a CV of ≈ 16% was reported maximal acceleration (Buchheit, Allen, et al., 2014). More details on the validity and reliability of the system used are provided elsewhere (Scott et al., 2016). To reduce the variability an exclusive GPS unit was allocated for each player during all games (Buchheit, Al Haddad, et al., 2014). For the analyzed games, the number of satellites for GPS was satisfactory 8-12, average 10.5 ± 2. The horizontal dilution of position (HDOP), which is a reflection of the geometrical arrangement of satellites and is related to both the accuracy and quality of the signal was not collected, which is a limitation.

Match running demands analysis

Computed running activity included: 1) total distance covered (TD, m), 2) distance covered between 13-18 km/h (m), 18-21 km/h (m), >21km/h (m), 3) number of acceleration between 2.5-4 $m.s^{-2}$ and >4 $m.s^{-2}$ 4) number of efforts >21 km/h and 5) peak speed attained during the match (km/h).

Statistical analysis

Variables are reported as CV with 90% confidence intervals (90%CI). We used a specifically designed spreadsheet (Hopkins, 2000b) to assess the between-matches variability in running performance in this spreadsheet, all analyses are performed on log-transformed data, which substantially reduce non-uniform errors. The coefficient of variation (CV, %) (i.e., the typical error expressed as a percentage of the mean score) was calculated for an easier comparison with the literature. The magnitude of the CV for the different running performance variables were expressed as standardized differences in the mean (effect size, ES), moreover the magnitude of the differences between first and second half CV was also calculated. The magnitude of the standardized differences was interpreted using Hopkins threshold: >0.2 (small), >0.6 (moderate), >1.2 (large) and > 2.0 (very large) (Hopkins, Marshall, Batterham, & Hanin, 2009). Confidence intervals (90%) for the (true) within/between-group differences were estimated (Hopkins et al., 2009). If the 90% confidence intervals overlapped small positive and negative values, the magnitude was deemed unclear; otherwise that magnitude was deemed to be the observed magnitude (Hopkins et al., 2009).

Results

The CV% and the standardized differences of the physical performance measurements are reported in the Table 1, 2 and 3. When all players were pooled together, CVs for the first half ranged from 5% for TD to ≈ 77% for number of acceleration >4 $m.s^{-2}$ and the magnitude of the CVs were rated from small to moderate (ES = 0.51- 0.98). High speed running activity (i.e., total distance covered at speeds 13-18 km/h, 18-21 km/h and >21 km/h) showed a small-to-moderate CV in the first (i.e., 13%-43%; ES = 0.51-0.71) and second half (i.e., 17%-53%; ES = 0.58-0.73) (Table 1). The CV was likely to increase with the running speed zones 13.3% (11.6;15.8) vs 42.9% (34.9;48.9) for distance covered 13-18 km/h vs >21 km/h, respectively for distance covered between 13-18 km/h and distance covered >21 km/h, respectively Lower CV were observed for low acceleration compared with the high acceleration zones (e.g., 16.3% (14.2;19.3) vs. 76.8% (65.3;95.3) for the number of accelerations 2.5-4 $m.s^{-2}$ vs > 4 $m.s^{-2}$, respectively).

Playing position had an effect on CV (Table 2 and 3). For example, CV for TD >13-18 km/h ranged from 3.4% for second strikers to 14.2% for strikers and the magnitude of the CVs were rated as small (ES = 0.41- 0.48) and 14.9% for wide-defenders vs 9.7% for wide-midfielders and the magnitude of the CVs were rated as moderate (ES = 0.79-0.80). Moreover, for peak speed CV ranged from 2.7% for second strikers to 10.1% for strikers and the magnitude of the CVs were rated as moderate (ES = 0.71- 1.15) and 5% for wide-defenders vs 3.7% for wide-midfielders and the magnitude of the CVs were small to moderate (ES = 0.51- 0.85).

Table 1. Between match variation of physical running performance

All pooled	Half 1	CV%	Standardized differences	Half 2	CV%	Standardized differences
Total distance (m)	5262.1 ± 460.9	5.3 (4.6;6.2)	0.57 (0.51;0.67)	4889.4 ± 481.9	5.17 (5.0;6.7)	0.59 (0.52;0.69)
D 13-18 km/h (m)	1015.8 ± 243.6	13.3 (11.6;15.8)	0.51 (0.45;0.59)	891.8 ± 224.5	17.4 (15.2;20.6)	0.58 (0.51;0.67)
D 18-21 km/h (m)	269.5 ± 83.3	21 (18.2;24.9)	0.60 (0.52;0.70)	235.2 ± 80.4	22.5 (19.5;26.7)	0.61 (0.54;0.72)
D >21 km/h (m)	211 ± 109.9	42.9 (36.9;51.8)	0.71 (0.62;0.83)	186.2 ± 95.6	53.0 (45.4;64.4)	0.73 (0.64;0.85)
# of Acc 2.5-4 (m/s/s)	56.3 ± 11.6	16.3 (14.2;19.3)	0.69 (0.61;0.81)	47.9 ± 10.9	18.1 (15.8;21.5)	0.69 (0.61;0.81)
# of Acc >4 (m/s/s)	4.6 ± 2.5	76.8 (65.3;95.3)	0.98 (0.86;1.15)	3.8 ± 2.2	89.7 (76.0;112.5)	0.98 (0.86;1.15)
# of efforts >21 (km/h)	11.7 ± 6	44.5 (38.3;53.8)	0.72 (0.64;0.85)	10.7 ± 5.1	49.0 (42.0;59.4)	0.73 (0.64;0.86)
Peak Speed (km/h)	29.0 ± 2.7	6.0 (5.2;7.0)	0.71 (0.62;0.83)	28.6 ± 2.4	7.7 (6.7;9.0)	0.87 (0.77;1.02)

Data are presented as mean ±SD or mean (90% confidence interval). **D:** Distance, **#:** number, **Acc:** accelerations, **CV%:** Coefficient of variation.

Table 2. Between match variation of physical running performance.

	Variables	Half 1	CV%	Standardized differences	Half 2	CV%	Standardized differences
Central Defender	Total distance (m)	4700.5 ± 351.2	5.0 (3.7;9.6)	0.68 (0.51;1.29)	4363.3 ± 477.5	4.5 (3.4;8.8)	0.49 (0.37;0.94)
	D 13-18 km/h (m)	783.6 ± 156.2	12.1 (8.9;24.2)	0.64 (0.48;1.21)	708.8 ± 168.9	16.3 (11.9;33.2)	0.68 (0.51;1.30)
	D18-21 km/h (m)	203.3 ± 66.6	26.2 (18.9;55.5)	0.91 (0.68;1.72)	180.3 ± 59.7	13.8 (10.1;27.7)	0.58 (0.43;1.10)
	D >21 km/h (m)	154.6 ± 92.1	51.2 (36.0;119.0)	0.91 (0.68;1.73)	124.7 ± 58.4	85.3 (58.3;222.1)	0.91 (0.68;1.72)
	# of Acc 2.5-4 (m/s/s)	55 ± 9.8	11.6 (8.5;23.1)	0.64 (0.48;1.21)	48.9 ± 9.9	13.9 (10.2;28.0)	0.63 (0.47;1.19)
	# of Acc >4 (m/s/s)	4.5 ± 2.1	90.4 (61.5;239.4)	1.16 (0.86;2.20)	4.1 ± 1.8	38.1 (27.2;84.6)	0.65 (0.48;1.23)
	# of efforts >21 (km/h)	8.3 ± 4.4	60.1 (42.0;144.3)	0.93 (0.69;1.76)	7.1 ± 3	69.0 (47.8;170.6)	0.84 (0.63;1.59)
	Peak Speed (km/h)	28 ± 2.9	5.9 (4.3;11.4)	0.49 (0.37;0.93)	28.5 ± 2.3	7.3 (5.4;14.3)	0.73 (0.55;1.39)
Wide defenders	Total distance (m)	5068.3 ± 307.5	5.5 (4.3;8.2)	0.81 (0.64;1.19)	4732.2 ± 346.8	8.2 (6.4;12.2)	0.89 (0.71;1.31)
	D 13-18 km/h (m)	889.9 ± 159.4	14.9 (11.6;22.6)	0.79 (0.62;1.16)	800.8 ± 179.9	21.5 (16.7;33.1)	0.71 (0.56;1.04)
	D 18-21 km/h (m)	240.7 ± 70.8	20.0 (15.5;30.6)	0.60 (0.47;0.87)	212.7 ± 70.7	27.8 (0.57;43.3)	0.72 (0.57;1.05)
	D >21 km/h (m)	203 ± 97.7	42.5 (32.3;68.0)	0.72 (0.57;1.05)	179.1 ± 82.5	37.2 (28.4;58.9)	0.61 (0.48;0.90)
	# of Acc 2.5-4 (m/s/s)	50.7 ± 9.3	15.7 (12.2;23.8)	0.73 (0.58;1.07)	44.5 ± 9.5	22.5 (17.4;34.6)	0.90 (0.71;1.31)
	# of Acc >4 (m/s/s)	4.2 ± 2.1	68.8 (51.2;115.5)	0.87 (0.69;1.28)	3.4 ± 1.7	91.2 (66.9;158.6)	1.05 (0.83;1.53)
	# of efforts >21 (km/h)	11.1 ± 5	52.5 (39.6;85.6)	0.83 (0.65;1.21)	10.6 ± 4.5	31.2 (23.9;48.8)	0.57 (0.45;0.83)
	Peak Speed (km/h)	29.3 ± 1.9	5.0 (4.0;7.5)	0.85 (0.67;1.24)	28.5 ± 2.5	9.3 (7.3;13.9)	1.04 (0.82;1.52)
Central midfielders	Total distance (m)	5476.9 ± 264.3	3.5 (2.4;6.9)	0.83 (0.59;1.63)	5066.4 ± 277.6	3.0 (2.1;6.1)	0.81 (0.57;1.59)
	D 13-18 km/h (m)	1170.1 ± 166.7	7.4 (5.2;15.2)	0.64 (0.46;1.26)	987.3 ± 162.6	14.2 (9.9;29.9)	0.73 (0.52;1.43)
	D 18-21 km/h (m)	265.1 ± 73	21.4 (14.7;46.5)	0.68 (0.48;1.33)	214.2 ± 62.7	26.1 (17.9;57.8)	0.64 (0.46;1.26)
	D >21 km/h (m)	146.1 ± 76.8	44.4 (29.8;106.2)	0.82 (0.58;1.61)	131.8 ± 63.6	88.7 (56.9;249.2)	1.14 (0.81;2.24)
	# of Acc 2.5-4 (m/s/s)	54.2 ± 9.3	20.4 (14.1;44.2)	1.10 (0.78;2.16)	43.7 ± 7.4	15.6 (10.8;33.0)	0.70 (0.50;1.38)
	# of Acc >4 (m/s/s)	3.4 ± 2.1	82.0 (53.3;277.1)	1.14 (0.81;2.52)	2.7 ± 1.7	174.8 (105.6;1293.3)	1.21 (0.86;3.15)
	# of efforts >21 (km/h)	8.3 ± 4.2	40.6 (27.4;95.6)	0.81 (0.57;1.59)	8 ± 3.6	83.0 (53.5;228.7)	1.25 (0.89;2.47)
	Peak Speed (km/h)	27.6 ± 2.4	6.4 (4.5;13.1)	0.78 (0.56;1.54)	27.3 ± 2	7.0 (5.0;14.3)	1.07 (0.76;2.10)

Data are presented as mean ±SD or mean (90% confidence interval). **D:** Distance, #: number, **Acc:** accelerations, **CV%:** Coefficient of variation.

Table 3. Between match variation of physical running performance

	Variables	Half 1	CV%	Standardized differences	Half 2	CV%	Standardized differences
Wide midfielders	Total distance (m)	5684.8 ± 231.6	3.6 (2.5;6.6)	0.91 (0.65;1.66)	5298.4 ± 266.7	3.9 (2.8;7.2)	0.72 (0.51;1.30)
	D 13-18 km/h (m)	1191.4 ± 152.8	9.7 (6.8;18.3)	0.80 (0.57;1.45)	1117.3 ± 181.6	14.8 (10.4;28.5)	0.79 (0.56;1.43)
	D 18-21 km/h (m)	352 ± 67	10.4 (7.3;19.6)	0.46 (0.33;0.84)	330.3 ± 51.8	10.1 (7.1;19.1)	0.71 (0.51;1.29)
	D >21 km/h (m)	335.7 ± 91.1	38.9 (26.3;81.4)	1.21 (0.86;2.20)	293.1 ± 79.1	25.6 (17.6;51.1)	0.99 (0.70;1.79)
	# of Acc 2.5-4 (m.s-2)	72.1 ± 9.7	8.7 (6.2;16.4)	1.17 (0.83;2.12)	61.0 ± 11.0	15.6 (10.9;30.0)	0.94 (0.67;1.70)
	# of Acc >4 (m.s-2)	7.1 ± 3	82.6 (53.5;198.2)	1.02 (0.72;1.84)	5.8 ± 2.4	39.3 (26.6;82.4)	0.92 (0.66;1.67)
	# of efforts >21 (km/h)	18.6 ± 4.8	37.8 (25.6;78.9)	1.23 (0.88;2.24)	16.2 ± 3.2	18.8 (13.0;36.7)	0.96 (0.68;1.74)
	Peak Speed (km/h)	31.0 ± 2.5	3.7 (2.6;6.9)	0.51 (0.36;0.93)	30.0 ± 2.0	5.4 (3.8;10.1)	0.84 (0.60;1.53)
Second strikers	Total distance (m)	5690.7 ± 289	3.0 (1.9;15.4)	1.07 (0.68;5.21)	5306.8 ± 292.3	6.0 (3.8;33.1)	1.06 (0.68;5.17)
	D 13-18 km/h (m)	1338.5 ± 142.4	3.4 (2.2;17.8)	0.41 (0.26;2.02)	1093.9 ± 142.2	14.2 (8.9;91.5)	1.00 (0.64;4.90)
	D 18-21 km/h (m)	339 ± 56.1	14.0 (8.8;90.0)	1.17 (0.75;57.00)	309 ± 75.4	10.6 (6.6;63.3)	0.67 (0.43;3.27)
	D >21 km/h (m)	212.2 ± 71.8	21.3 (13.2;157.3)	0.82 (0.52;4.00)	216 ± 82.5	43.1 (25.7;475.7)	0.96 (0.61;4.69)
	# of Acc 2.5-4 (m.s-2)	62.9 ± 12.4	30.2 (18.4;263.8)	0.72 (0.46;3.49)	53.9 ± 10.5	17.0 (10.6;115.4)	0.65 (0.41;3.17)
	# of Acc >4 (m.s-2)	5.3 ± 2.4	68.2 (39.4;1168.0)	1.12 (0.72;5.50)	4.7 ± 3	61.1 (35.7;929.3)	1.23 (0.79;6.01)
	# of efforts >21 (km/h)	12.2 ± 4.7	7.1 (4.5;39.6)	0.39 (0.25;1.91)	12.9 ± 4.5	36.0 (21.7;348.6)	0.86 (0.55;4.20)
	Peak Speed (km/h)	28.8 ± 2.3	2.7 (1.7;13.8)	0.71 (0.45;3.46)	28.9 ± 2.5	6.3 (4.0;34.6)	0.91 (0.58;4.45)
Strikers	Total distance (m)	5330.6 ± 401.6	4.8 (3.4;13.0)	0.83 (0.59;2.17)	4934.5 ± 464.2	6.4 (4.5;13.1)	0.57 (0.41;1.13)
	D 13-18 km/h (m)	914 ± 183.1	14.2 (10.0;41.80	0.48 (0.34;1.25)	800.8 ± 191.9	22.6 (15.7;49.8)	0.71 (0.51;1.40)
	D 18-21 km/h (m)	298.8 ± 65.7	10.7 (7.6;30.7)	0.58 (0.42;1.53)	254.1 ± 66.1	23.9 (16.5;52.9)	0.72 (0.52;1.43)
	D >21 km/h (m)	303.7 ± 81.9	23.6 (16.5;74.5)	0.92 (0.66;2.41)	263.5 ± 86.7	35.0 (23.9;81.2)	0.88 (0.63;1.75)
	# of Acc 2.5-4 (m.s-2)	53.5 ± 8	19.0 (13.3;57.9)	0.91 (0.65;2.38)	44.4 ± 9.4	17.7 (12.3;38.1)	0.67 (0.48;1.33)
	# of Acc >4 (m.s-2)	4.7 ± 2	63.6 (42.5;264.4)	1.16 (0.83;3.05)	3.8 ± 2.2	74.9 (49.1;203.2)	0.92 (0.66;1.82)
	# of efforts >21 (km/h)	17.1 ± 5	26.2 (18.2;84.2)	0.77 (0.55;2.02)	14.5 ± 4.9	42.5 (28.8;101.8)	0.92 (0.66;1.82)
	Peak Speed (km/h)	30.5 ± 2.7	10.1 (7.1;23.9)	1.15 (0.82;2.56)	29.9 ± 2	5.0 (3.6;10.2)	0.83 (0.60;1.65)

Data are presented as mean ±SD or mean (90% confidence interval). **D:** Distance, **#:** number, **Acc:** accelerations, **CV%:** Coefficient of variation.

Discussion

This study examined for the first time the match-to-match variation of physical performance in professional soccer players during official soccer matches over two consecutive season using GPS technology. Our results show that 1) match-to-match CV ranged from 5.3% to 70% for the different locomotor variables, 2) the CVs were likely to increase with running/acceleration intensity and 3) CVs were differently affected by playing position.

The total distance was the most stable variable for all playing positions with a CV ranging from 3.5-5.5% for the first half and 3.0-8.2% for the second half, with an unclear difference between the first and the second half (Table 1-3). These results are in line with previous observations using camera-based tracking systems reporting a smaller CV for total distance compared with other running distance variables (Rampinini et al., 2007). The CV was likely to increase with the running speed zones CV= 13.3% and 42.9% for distance covered between 13-18 km/h and distance covered >21 km/h, respectively. This is in line with previous observations using camera-based tracking systems (Gregson et al., 2010; Rampinini et al., 2007) showing that higher speed running zones were likely to present a greater variability compared with the lower speeds. In the present study, the GPS-derived CV values obtained for distances covered at different speed bands are likely to represent game-related changes in running demands as the reported between-unit variation during a standardized task ranged from 2% (TD >14.4 km/h) to 6% (TD >25.1 km/h) (Buchheit, Al Haddad, et al., 2014).

In the present study, we present for the first time GPS-derived data related to the variability of accelerations obtained during official games in elite professional soccer players. Similar to the distance covered at different speeds, the number of accelerations performed at high accelerations was more variable than the number of low accelerations. In line with our results, Akenhead et al. (Akenhead, French, Thompson, & Hayes, 2014) reported a greater CV for high magnitude accelerations (4 $m.s^{-2}$) compared with lower magnitude accelerations (2-3 $m.s^{-2}$) (47% vs. 3.1%, respectively) in standardized tasks. Similarly, between-unit variability increased with higher accelerations (e.g., 31% vs 43%) during a standardized task (Buchheit, Al Haddad, et al., 2014). The relatively high CV scores reported for accelerations in the present study and elsewhere (Akenhead et al., 2014; Buchheit, Al Haddad, et al., 2014) would suggest that practitioners should be careful when interpreting acceleration-derived indices to monitor game/training physical performance. Similarly, the match-to-match variability of peak speed reached in the game (CV = 6%-10%; ES = 0.49-1.15) was 3- to 10-fold higher than the reported reliability (i.e., 1% to 2.3%) of this variable using GPS devices (Buchheit, Al Haddad, et al., 2014; Coutts & Duffield, 2010). This small-to-moderate between games variability in the peak speed would indicate that the soccer players are likely to reach regularly high peak speed in the games and would suggest that soccer players should be physically prepared for this (Al Haddad, Simpson, Buchheit, Di Salvo, & Mendez-Villanueva, 2015; Mendez-Villanueva, Buchheit, Simpson, Peltola, & Bourdon, 2011; Suarez-Arrones et al., 2014; Torreno et al., 2016). Alongside with the between unit-variability, this greater game-related variability is likely related with different factors such as physical and mental fatigue, pacing, and changes in tactical roles and playing styles associated with opponent player/team which affect the interaction of the player with the actual environment (Al Haddad et al., 2015; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Paul, Bradley, & Nassis, 2015).

We provided, also for the first time, detailed GPS-derived match-to-match variability data on specific playing positions (Table 2 and 3). Similar to a previous report (Gregson et al., 2010), we found likely between-position differences in CV for some variables. For example, wide midfielder showed a smaller CV compared with central midfielder for the distance covered between 13-18 km/h (10.4% vs 21.4%) and the peak speed reached (3.7% vs 6.4%) during the game. These differences in match-to-match variability between the different playing position is likely multifactorial and could be associated with the different between game demands (i.e., fatigue pacing strategies, and changes in tactical roles associated with opponent) (Paul et al., 2015). Thus, for a more detailed assessment of locomotor performance, position specific CVs are recommended.

The relatively high CVs reported for high-speed locomotor variables have important implications for assessing and interpreting match/training physical performance and monitoring training load in soccer players. For example, the high match-to-match variability reported for players' high-speed locomotor activities suggests that players do not consistently produce their maximal efforts within games. As such, match-related high-speed locomotor performance might not be a good indicator of player's physical performance (Mendez-Villanueva & Buchheit, 2011). Moreover, because the CV value is typically higher than the calculated for the “smallest worthwhile change/difference”, the ability to detect small, moderate or even large real changes/differences in player’s high-speed locomotor performance can be compromised (Hopkins, 2000a).

For example, the thresholds for small, moderate and large (0.2, 0.6 and 1.2 x between-subject SD, respectively) differences in the number of accelerations >4 $m.s^{-2}$ in a CD are 9.3%, 27.9% and 55.8% (data computed from Table 2). Because the CV for this particular playing position and variable was much higher (i.e., 94.4%), the responsiveness of that variable needs to be quite high before likely worthwhile changes/differences might be detected. While reliability, and associated usefulness parameters are important aspects to consider when monitoring and assessing players’ performance, responsiveness is considered the most essential property of an evaluative instrument (Impellizzeri & Marcora, 2009). That is, the ability to detect practically useful changes over a particular time frame is what ultimately should determine the practical usefulness of a performance measure. It is also worthwhile indicating that the use of the GPS during soccer games could be problematic in stadium with high rise stands or over hanging stands which could weaken the signal resulting in poor data accuracy.

Conclusions

In conclusion, GPS-derived match-to-match variability in official games’ locomotor performance of professional soccer players is high, particularly for high-speed variables, due to the complexity of match running performance and its most influential factors and reliability of the devices (Andrzejewski et al., 2016; Paul et al., 2015). Moreover, playing position can affect the magnitude of such variability. An awareness of that variability associated with that variables typically employed to prescribe and/or monitor training intensity/load appears crucial before practitioners can use this data to support performance enhancement strategies.

Manipulation of training contents to optimize competitive performance is at the core of training monitoring and prescription in soccer. As such, a detailed knowledge of the match running demands can help in designing soccer-specific drills that meet player’s needs (Di Salvo & Pigozzi, 1998). In this regard, training load monitoring during training in soccer players frequently includes the quantification, via GPS devices, of high-intensity running actions such as high-speed running and/or accelerations (Malone et al., 2015). Therefore, the knowledge of typical variation from game-to-game of the locomotor variables of interest is pivotal to evaluate real changes/ differences in match play and training intensity and load. This would eventually facilitate effective planning and timing of subsequent training and recovery sessions to ensure the required physiological stimuli is applied.

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CAPÍTULO 5.
CONCLUSIONES, LIMITACIONES Y PLANTEAMIENTOS DE FUTURO

(CONCLUSIONS, LIMITATIONS AND FUTURE APPROACHES)

"Aquellos que dudan de todo, son aquellos que más aciertan"

PEP GUARDIOLA

Conclusiones (Conclusions)

En este apartado se muestran las conclusiones de los estudios realizados, sus limitaciones, así como las posibles líneas de investigación derivadas de los estudios llevados a cabo en esta tesis.

El análisis de los patrones de movimiento en fútbol profesional durante partidos oficiales, hasta la publicación de los presentes trabajos, se habían llevado a cabo a través de diferentes sistemas de observación empleando generalmente sistemas notacionales, o de grabación a través de cámara o multi-camara (V. Di Salvo et al., 2013). Gracias a los resultados de la presente tesis doctoral, los entrenadores y preparadores físicos podrán acceder a unas demandas de competición analizadas a través de tecnología GPS y respuesta de la frecuencia cardiaca. El uso de esta tecnología es empleada de manera habitual en el día a día por los clubs, tanto para analizar sus entrenamientos como monitorizar la carga.

Con la realización de estos estudios hemos podido llegar a las siguientes conclusiones:

- Actualmente el conocimiento y exactitud sobre las exigencias condicionales requeridas por los jugadores de fútbol profesional durante la competición, ha sido ampliado, incorporando, por primera vez, información proveniente de sistemas GPS y monitorización de la FC durante partidos oficiales.

- La valoración de la carga externa e interna durante partidos oficiales con GPS, es el primer paso para diseñar ejercicios de entrenamiento adaptados a los puestos específicos, con el objetivo de reproducir las demandas de competición.

- Nuestros resultados, mostraron a través de la monitorización de los patrones de movimiento e intensidad del ejercicio, demandas distintas para los diferentes puestos específicos. Esta información, podrá emplearse para desarrollar tareas de entrenamiento específicas por posición basadas en un similar módulo táctico.

- Varios ejercicios de entrenamiento pueden provocar cargas internas similares a la competición, provocando óptimos estímulos fisiológicos, pero con patrones de movimiento inapropiados comparados con la realidad competitiva. Como alternativa, las actividades de entrenamiento con objetivos condicionales, deberán diseñarse para replicar las demandas locomotoras específicas por puestos con estímulos similares a la competición.

- En base a nuestros resultados, podemos afirmar que aquellos puestos específicos con un mayor rendimiento de carrera en competición, presentan valores más elevados en su Eff_{index}.

- La reducción en los patrones de movimiento que los jugadores manifiestan a medida que avanza el partido, junto con la sustancial reducción del Eff_{index} por la mayoría de puestos específicos, podría asociarse a una disminución del rendimiento físico del jugador o posible estado de fatiga (Bangsbo, Mohr, & Krustrup, 2006; Mohr, Krustrup, & Bangsbo, 2003; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). Por otro lado, también debemos tener en cuenta la complejidad del juego y las variables situacionales o contextuales, las cuales puedan influir sustancialmente en los patrones de movimiento de los jugadores (Lago et al. 2010).

- Nuestros resultados reflejaron que el CV osciló partido a partido entre el 5.3% y el 70% en función de las diferentes variables locomotoras. La magnitud de este CV se incrementa a medida que aumenta la intensidad de carrera y/o aceleración, siendo también influenciado de manera diferente según la posición específica de juego. Esta información sobre la variabilidad partido a partido, empleando en nuestro caso tecnología GPS, deberá tenerse en cuenta cuando se utilicen estas variables, tanto para prescribir entrenamientos basados en las demandas de competición, como para monitorizar carga o intensidad del entrenamiento.

Limitaciones (Limitations)

- Nuestro tamaño de muestra era relativamente pequeño e incluía datos de un solo equipo. Por lo tanto, los resultados de este estudio pueden ser específicos para estos jugadores de equipo y para la estructura adoptada por el cuerpo técnico. En consecuencia, se necesitan estudios adicionales que involucren un mayor número de equipos participantes para establecer resultados más representativos.

- El GPS ha demostrado ser un método válido para medir la distancia recorrida de velocidades bajas a moderadas pero no altas (Johnston et al., 2012). La fiabilidad del GPS disminuye con el aumento de la velocidad de movimiento. Por lo tanto, debe tenerse precaución al interpretar las demandas individuales de movimiento realizadas a velocidades más altas. En consecuencia, se requieren más estudios con los sistemas GPS actualmente disponibles que registren una mayor frecuencia de muestreo para replicar nuestros hallazgos y mejorar la fiabilidad y validez de los resultados.

Planteamientos de futuro (Future approaches)

En la presente tesis doctoral hemos intentado responder a varias de las cuestiones e inquietudes que nos habíamos planteado como entrenadores e investigadores. Sin embargo, el entorno tan variable y complejo del fútbol, invita a seguir investigando con el objetivo de profundizar en el conocimiento sobre la optimización de la prestación del jugador durante la competición oficial, nuestro "Gold Standard".

En el fútbol, existe en ocasiones una tendencia a analizar e investigar los aspectos técnicos, tácticos y físicos por separado (Mackenzie & Cushion, 2013), desde una perspectiva más reduccionista. Este tipo de análisis, limita el entendimiento y aplicación de los datos obtenidos. Desde mi perspectiva como entrenador, el análisis del rendimiento debe ser realizado desde una visión más holística, integrando todos los factores (técnicos, tácticos, físicos y psicológicos) que puedan afectar al futbolista, y así tratar de conocer más en profundidad aquellos que pueden determinar el éxito de los equipos en la competición.

A continuación, en base a esto, plantearemos objetivos que podrán encauzar futuras líneas de trabajo o investigación relacionadas con contenidos de la presente tesis doctoral, desde un punto de vista más holístico:

- Evaluar las demandas físicas y respuesta fisiológica durante partidos oficiales empleando GPS y FC, relacionando variables como los patrones de movimiento o intensidad del ejercicio, con diferentes estructuras o sistemas tácticos de juego.

- Analizar las demandas físicas y respuesta fisiológica durante partidos oficiales empleando GPS y FC, relacionando estas variables condicionales con diferentes contextos situacionales.

- Comprobar y comparar los CV partido a partido, analizando los mismos en función de diferentes contextos o variables situacionales.

- Evaluar la metodología de entrenamiento utilizada a lo largo de la semana en base al comportamiento de los jugadores y juego desarrollado por el equipo durante el partido. Esto nos proporcionaría valiosa información acerca de si la línea de trabajo ha sido adecuada para poder tener éxito en el proceso enseñanza - aprendizaje.

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ANEXOS

(ANNEXED)

ARTÍCULOS ORIGINALES PUBLICADOS EN REVISTAS JCR

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Match-play activity profile in professional soccer players during official games and the relationship between external and internal load

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Original Article

Match-play activity profile in professional soccer players during official games and the relationship between external and internal load

Short title: Physical demands in professional soccer players

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Abstract

Aim: The aim was to quantify for the first time the physical and physiological profile of professional soccer players in official games using GPS and heart rate response. **Methods**: Thirty professional soccer players were investigated during a half in competitive club level matches (*n*=348) using GPS devices. **Results**: The relative total distance was 118.9±10.7 $m \cdot min^{-1}$ and player's work-to-rest ratio was 2.1:1. Defenders covered the lowest total distance, while Second-Strikers (2^{nd}S) and Wide-Midfielders (W-MD) traveled the greatest total distance. Defenders presented the lowest work-to-rest ratio values. Playing position also impacted on all sprinting performance results, except in average sprint distance and time of sprint. The number of sprints and repeated-sprint sequences recorded by the W-MD and Strikers (S) were significantly greater than any other group. The average Heart Rate (HR) recorded was 87.1%HR_{max} and the relationship between the external and internal load value (effindex) was 1.4 with significant differences in both between playing positions. W-MD recorded a significantly smaller average HR than any other group and Centre-Backs showed a significantly smaller effindex value than any other group. Conversely, W-MD showed a significantly greater effindex value than any other group, except the 2^{nd}S. **Conclusion**: This study has verified a number of statistically significant differences between the different playing positions. Coaches should be focused on the specific physical and physiological requirements of the playing positions to optimize the training prescription in soccer. The relationships between external and internal load measures among position-specific indicates that players with less overall running performance during match-play were the worst in effindex.

Keywords: team sport, time motion, GPS, football

Introduction

Football is a predominantly aerobic sport, interspersed with frequent bouts of high-speed movements [1,2]. Understanding the physical demands of match-play is important in order to optimise the training process, since specific protocols can then be designed in accordance with these demands [3].

Over the years, numerous techniques have been used to determine the physical profile of soccer players [3-5]. In this context, the recent introduction of GPS technology for monitoring both training and competitive events provides a reliable and valid measure of the physical profile [6,7]. Furthermore, the use of GPS looks set to increase our knowledge by revealing how a soccer player's physical profile evolves with age [8], how it varies according to the playing position [8,9], and between competitive versus training contexts [4]. Due to the differences between video-based analysis system and GPS devices care should be taken when using data from them interchangeably to log the external load on soccer players [10,11].

Although GPS devices are now being used during training by numerous soccer clubs, very little information is available about their application to the study of physical profiles in players during competition. Some studies have used GPS devices to describe the physical profile among young soccer players in different age categories [8,9], semi-professional soccer players [4] in friendly matches, or acceleration profile in Australian soccer players [2]. No published studies have described the physical and physiological profile of European professional soccer players using GPS technology in official games. Accordingly, the aim of this study was to quantify for the first time the physical and physiological profile of elite European professional soccer players in official games using GPS and heart rate response, quantifying the dose-response of the match stimulus (external and internal load).

Materials and methods

Subjects

Time-motion analysis of running activity and heart rate response was collected in 30 elite European professional soccer players (~14h of training per week). The participants were informed in detail about the experimental procedures and the possible risks and benefits of their participation. The study was approved by the Research Ethics Committee of Pablo de Olavide University and written informed consent was obtained from all participants. Players were informed that they could refuse to participate in the study.

Experimental protocol

An observational design was used to examine the physical demands and exercise intensity in male soccer players during competitive matches using GPS technology and HR response. Thirty elite professional outfield players from the same team were investigated during competitive club level matches in the national league, national cup, and national super cup. Match analyses were performed 4-15 times on each player over a period of two seasons (*n* = 348). At the same time, the team also was participating in the Champions League or UEFA Europa League, depending on season. Tactically, the team used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a "second striker". In order to reduce possible fatigue, tactical changes or the possible influence of the result in the running performance during the second half, only the first half was analysed to describe movement patterns during match-play (45-min each plus additional time). Only time-motion data of players who participated in the entire half were retained for the subsequent analyses. GPS and heart rate (HR) data were used to provide quantitative information on match-play.

Activity pattern measurements

Players were required to wear a GPS unit (SPI Pro X; GPSports Systems, Canberra, Australia) during the game, which was fitted to the upper back (i.e., between the shoulder blades) of each player using an adjustable neoprene harness. The devices were switched on ~10 minutes before the game and immediately switched off at the end. The data stored includes HR, time, speed, distance, accelerations and impacts ("*g*" force). GPS data were recorded at 5 Hz and accelerometer data at 100 Hz respectively. The validity and reliability of the GPS system have been previously reported [6,12] and used in soccer players [2,4,8,9].

Match running demands analysis

Only the time-motion data for players who participated in the entire first half were retained and only were analysed the minutes of the match-play. Time-motion data from all players were analysed with the software designed to provide objective measures of physical match performance. The players' activities were coded into five categories and speed thresholds [4]: walking (0.1-7.0 $km \cdot h^{-1}$), running at low-speed (7.1-13.0 $km \cdot h^{-1}$), at medium-speed (13.1-18.0 $km \cdot h^{-1}$), at high-speed (18.1-21.0 $km \cdot h^{-1}$), and at sprint (>21.0 $km \cdot h^{-1}$). The above categories were divided in two further locomotor categories to provide an estimation of player exercise-to-rest ratios; (a) low-speed activity (0.1-7 $km \cdot h^{-1}$) and (b) moderate-and-high-speed activity (>7.0 $km \cdot h^{-1}$). Sprint activities were defined as at least 1-s run >21 $km \cdot h^{-1}$. Repeated-sprint sequence (RSS) was defined as a minimum of two consecutive ≥1-s sprints interspersed with a maximum of 60-s of recovery.

Exercise intensity

Match exercise intensity was quantified by monitoring heart rate (HR) during each game. HR was continuously measured with short-range telemetry (SPI-Pro-X, GPSports, Australia) and was expressed in relation to the individual maximal HR (HR_{max}) obtained throughout an incremental field test [13] (the highest 5-s average recorded during the test) or during the course of the match if the HR_{max} was higher than the value obtained during the test.

Relationship between external and internal load measures

The performance efficiency (Effindex) for the quantification of the dose-response of the match stimulus was calculated as [mean speed in $m \cdot min^{-1}$/mean exercise intensity ($\%HR_{max}$)] for every entire first half [14-16]. This index integrates mean speed (i.e. external load) with respect to the relative cardiovascular stress (i.e. internal load) during the match-play into a single parameter [14].

Statistical analysis

All statistical tests were performed using the Social Sciences package (SPSS, 2010, IBM SPSS Statistics 19 Core System User's Guide; SPSS Inc., Chicago, IL). Descriptive statistics were calculated on each variable and Shapiro-Wilk test were used to verify normality. A one-way analysis of variance (ANOVA) was used to determine differences between playing positions. In the event of a significant difference, Bonferroni's post-hoc tests were used to identify any localized effects. Statistical significance was set at $P<0.05$. Data are presented as means and standard deviations (SD).

Results

Movement Analysis

The relative total distance (RTD) (±SD) covered during the half was 118.9 ± 10.7 $m \cdot min^{-1}$. As a percentage of this distance, 32.2% (38.3 ± 4.5 $m \cdot min^{-1}$) was spent walking, 38.4% (45.7 ± 6.7 $m \cdot min^{-1}$) running at low-speed, 19.7% (23.4 ± 5.8 $m \cdot min^{-1}$) at medium-speed, 5.4% (6.4 ± 2.1 $m \cdot min^{-1}$) at high-speed and 4.2% (5.0 ± 2.5 $m \cdot min^{-1}$) at sprint. Player's work-to-rest ratio was 2.1:1. Match running profiles are shown in Table 1. Playing position significantly impacted on distance covered during the half (45-min) and on work-to-rest ratio. Defenders covered the lowest RTD. Centre-Backs (CB) covered a >18 $km \cdot h^{-1}$ distance significantly shorter than any other group. Conversely, Second-Strikers (2^{nd}S) and Wide-Midfielders (W-MD) covered the greatest RTD. W-MD covered a >18 $km \cdot h^{-1}$ and >21 $km \cdot h^{-1}$ distance significantly greater than any other group. Defenders presented the lowest work-to-rest ratio values. CB showed a significantly smaller work-to-rest ratio than any other group, whereas Strikers (S) did not show significantly greater values than defenders.

The number of sprints, average sprint distance and maximal sprint distance during the half (45-min) were: 12.7 ± 6.1 sprints, 18.2 ± 3.4 m, and 35.1 ±11.3 m, respectively. Sprint duration was 2.50 ± 0.5 s with one sprint being performed on average every 4.1 ± 2.4 min and the number of RSS during the half (45-min) was 3.1 ± 2.9. Playing position significantly impacted on all sprinting performance results, except in average sprint distance and time of sprint. The number of sprints and RSS recorded by the W-MD and S were significantly greater than any other group. The maximal sprint distance and average minutes between sprints recorded by the W-MD were significantly greater and smaller, respectively, than any other group, except the S (Table 2).

Exercise intensity

The average HR recorded during the half was 87.1% HR_{max} with significant differences between playing positions. W-MD recorded a significantly smaller average HR than any other group (Figure 1).

Relationship between external and internal load measures

The effindex value was 1.4 with significant differences between playing positions. CB showed a significantly smaller effindex value than any other group. Conversely, W-MD showed a significantly greater effindex value than any other group, except the 2^{nd}S (Figure 1).

Discussion

The aim of this study was to quantify for the first time the physical and physiological profile of elite professional soccer players in official games using GPS and heart rate response. The main findings of the present study reflected that 1) playing position impacted significantly on relative distance covered, work-to-rest ratio, sprinting performance results and average HR, and 2) relationships between external and internal load measures among position-specific players indicated that those with less overall running performance during match-play showed the worst results in effindex.

The overall running-patterns (119 $m \cdot min^{-1}$) and sprinting performance results in the present study were higher than those previously reported in semi-professional soccer players [4] (113 $m \cdot min^{-1}$), Australian soccer players [17] (104 $m \cdot min^{-1}$) and youth soccer players [8] (ranging from 93.5 to 108.8 $m \cdot min^{-1}$), indicating that elite European professional soccer official games are played at higher relative running demands. The work-to-rest ratio values (2.1:1) in the present study were smaller than those reported in semi-professional soccer players [4] (2.4:1). These data suggest that higher playing standards in soccer might be associated with overall increased running demands and sprinting performance. However, comparisons should be made with caution because different GPS systems [10-Hz [4], 5-Hz [17] and 1-Hz [8]] and time-motion analysis methods were employed (0.1-7 $km \cdot h^{-1}$ for rest in the present study vs. 0.1-4 $km \cdot h^{-1}$ in semi-professional soccer players), and previous studies revealed rather large between-system differences in the determination of distance covered [10,11]. Nevertheless, the present study reflects the specific demands during match-play (official games) in professional soccer players using GPS devices, and can be used to develop position-specific training tasks based on this tactical formation. Also, the work-to-rest ratio obtained can also help coaches to plan specific intermittent exercise training protocols.

Defenders presented the lowest values of RTD and work-to-rest ratio. CB showed the lowest values of distance at high-speed, work-to-rest ratio and effindex, while 2^{nd}S and W-MD presented the highest values of RTD and effindex. W-MD was the playing position with significantly lowest average HR, highest high-speed running and sprinting values. Probably, the wide differences between CB and W-MD observed in the current study could be related to the tactical roles and training adaptations. W-MD have a linking role in the team and need to complete fast movement away from defending players, take advantage on goal scoring opportunities [18] and also back to defend when their team lose the ball. While the average sprint distance was similar for all specific positions (~ 18 m), with this tactical formation and game philosophy W-MD presented the highest values in maximal sprint distance and the highest number of RSS (41 m and 6 RSS during the half, respectively), excluding the S who reported similar values (39 m and 5 RSS during the half, respectively). Specific positions showed maximal sprint distance from 32 to 41 m with averages of peaks of speed from 28 to 31 km·h^{-1}. A previous study reported as a rule, speed sessions typically conducted by fitness trainers include short sprints (< 20 m) [19]. Therefore, this information should be used for the prescription of drills that replicate game repeated-sprint sequences, sprint distances and peaks of speed, in order to prescribe specific trainings adapted to individual game demands; and the assessment of running speed in developing players should therefore include assessment of both acceleration and distances ~ 40 m [19].

Our results confirm data on position-specific running patterns reported in adult soccer players using video-analysis [3,20] or in youth soccer players [21]. Therefore, this information reflects that players have specific demands during match-play and can be used to develop position-specific training strategies. Moreover, the effindex expressed how efficiently one can run with a given cardiovascular stress [14]. Accordingly, the relationships between external and internal load measures among position-specific in the present study indicates that players with less overall running performance during match-play were the worst in effindex.

Conclusion

The assessment of the external (i.e., running demands using GPS devices) and internal (i.e., HR responses) load imposed during the competition is the first step preceding the design of position-specific conditioning training tasks controlled with this technology. This study has quantified physical and physiological demands of professional soccer players with GPS and HR response and has verified a number of statistically significant differences between the different playing positions. Coaches should be focused on the specific physical and physiological requirements of the playing positions to optimize the training prescription in soccer. Future studies in professional soccer players adding physical performance assessments and using relative intensity zones during official games are needed.

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Table 1. Match running profile (only first half) in professional soccer players (n = 348). Data are mean ± SD.

Table 2. Sprinting performance results obtained during matches (only firs half) in professional soccer players (*n* = 348). Data are mean ± SD.

Figure 1. Average Heart Rate expressed in relation to the individual maximal HR (HR_{max}) and Effindex during the half in professional soccer players (*n* = 348). Data are mean ± SD.
CB: Centre Backs; **FB:** Full Backs; **MD**: Midfielders; **W-MD**: Wide Midfielders; **2^ns^S**: Second Strikers; **S**: Strikers.
a: Significant difference *vs.* CB; **b**: Significant difference *vs.* FB; **c**: Significant difference *vs.* MD; **d**: Significant difference *vs.* W-MD; **e**: Significant difference *vs.* 2nd S; **f**: Significant difference *vs.* S; *****: Significantly smaller than any other group.

Table 1. Match running profile (only first half) in professional soccer players (n = 348). Data are mean ± SD.

Variables	CB (*n* = 53)	FB (*n* = 57)	MD (*n* = 79)	W-MD (*n* = 68)	2^{nd} S (*n* = 44)	S (*n* = 47)
Relative total distance ($m \cdot min^{-1}$)	$103.7 \pm 7.3^{*}$	$112.8 \pm 6.7^{c,d,e,f}$	122.6 ± 6.8^{e}	125.6 ± 6.9	127.7 ± 6.8	$119.1 \pm 8.7^{d,e}$
RD: 0.1 - 7.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	40.7 ± 3.3	39.3 ± 4.2	$36.8 \pm 2.9^{a,b,f}$	$36.3 \pm 3.1^{a,b,f}$	$36.8 \pm 4.2^{a,b,f}$	41.0 ± 5.7
RD: 7.1 - 13.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	$38.2 \pm 4.7^{b,c,d,e,f}$	$43.6 \pm 4.9^{c,d,e}$	50.0 ± 5.8	47.6 ± 4.4	48.2 ± 5.3	$43.9 \pm 7.8^{c,d,e}$
RD:13.1 - 18.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	$17.1 \pm 3.2^{b,d,e,f}$	$19.8 \pm 3.7^{c,d,e}$	26.2 ± 4.8^{e}	25.8 ± 3.9^{e}	29.7 ± 3.5	$20.9 \pm 4.6^{c,d,e}$
RD:18.1 - 21.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	$4.4 \pm 1.4^{b,d,e,f}$	$5.4 \pm 1.6^{d,e,f}$	$6.0 \pm 1.9^{d,e}$	8.1 ± 1.6	7.9 ± 1.8	$6.5 \pm 1.4^{d,e}$
RD: >21.0 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	$3.3 \pm 1.9^{b,d,e,f}$	$4.6 \pm 2.2^{d,f}$	$3.4 \pm 1.7^{b,d,e,f}$	$7.6 \pm 2.1^{+}$	$5.0 \pm 1.8^{d,f}$	6.6 ± 1.8^{d}
RD: >13 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	$24.7 \pm 5.2^{b,c,d,f}$	$29.9 \pm 6.3^{c,d,e,f}$	$35.6 \pm 6.8^{d,e}$	41.6 ± 6.3	42.6 ± 5.2	$34.0 \pm 6.0^{d,e}$
RD: >18 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	$7.6 \pm 2.9^{*}$	$10.0 \pm 3.4^{d,e,f,}$	$9.4 \pm 3.2^{d,e,f}$	$15.7 \pm 3.2^{+}$	12.9 ± 3.1^{d}	13.1 ± 2.7^{d}
Work-to-rest ratio (RD>7.0 $km \cdot h^{-1}$/ RD≤7.0 $km \cdot h^{-1}$)	$1.56 \pm 0.25^{*}$	$1.90 \pm 0.36^{c,d,e}$	2.34 ± 0.33^{f}	2.15 ± 0.50^{f}	2.51 ± 0.46^{f}	1.95 ± 0.49

CB: Centre Backs; **FB:** Full Backs; **MD**: Midfielders; **W-MD**: Wide Midfielders; **2nsS**: Second Strikers; **S**: Strikers. **RD**: Relative distance.

a: Significant difference *vs.* CB; **b**: Significant difference *vs.* FB; **c**: Significant difference *vs.* MD; **d**: Significant difference *vs.* W-MD; **e**: Significant difference *vs.* 2^{nd}S; **f**: Significant difference *vs.* S; *: Significantly smaller than any other group; +: Significantly greater than any other group.

Table 2. Sprinting performance results obtained during matches (only firs half) in professional soccer players (n = 348). Data are mean ± SD.

Variables	CB (n = 53)	FB (n = 57)	MD (n = 79)	W-MD (n = 68)	2^{nd} S (n = 44)	S (n = 47)
Number of Sprints	$7.9 \pm 3.9^{b,d,e,f}$	$11.3 \pm 4.8^{d,f}$	$8.9 \pm 4.4^{b,d,e,f}$	18.7 ± 5.2	$13.2 \pm 4.5^{d,f}$	16.6 ± 4.7
Average time of sprint (s)	2.5 ± 0.7	2.5 ± 0.5	2.4 ± 0.5	2.6 ± 0.3	2.4 ± 0.5	2.5 ± 0.3
Average minutes between sprint	$5.7 \pm 2.8^{b,d,e,f}$	$4.4 \pm 2.7^{d,f}$	$5.4 \pm 2.7^{d,e,f}$	2.5 ± 0.9	3.7 ± 1.5^{d}	2.8 ± 0.8
Average Sprint Distance	18.4 ± 4.3	18.7 ± 3.8	17.6 ± 3.4	18.6 ± 2.7	17.6 ± 3.4	18.2 ± 2.7
Maximal Sprint Distance	$31.8 \pm 12.7^{d,f}$	34.6 ± 10.2^{d}	$31.1 \pm 10.6^{d,f}$	41.0 ± 10.0	34.0 ± 10.2^{d}	38.8 ± 10.8
Maximal Speed	$27.9 \pm 2.7^{b,d,f}$	29.3 ± 1.8	$27.7 \pm 2.4^{b,d,f}$	31.0 ± 2.8	$28.5 \pm 2.1^{d,f}$	30.1 ± 2.3
RSS	$1.0 \pm 1.7^{b,d,e,f}$	$2.5 \pm 2.2^{d,f}$	$1.7 \pm 1.7^{d,e,f}$	5.8 ± 3.2	$3.2 \pm 2.5^{d,f}$	4.8 ± 2.8

CB: Centre Backs; **FB:** Full Backs; **MD**: Midfielders; **W-MD**: Wide Midfielders; **2^{ns}S**: Second Strikers; **S**: Strikers. **RSS**: Repeated-sprint sequence.

a: Significant difference *vs.* CB; **b**: Significant difference *vs.* FB; **c**: Significant difference *vs.* MD; **d**: Significant difference *vs.* W-MD; **e**: Significant difference *vs.* 2^{nd}S; **f**: Significant difference *vs.* S.

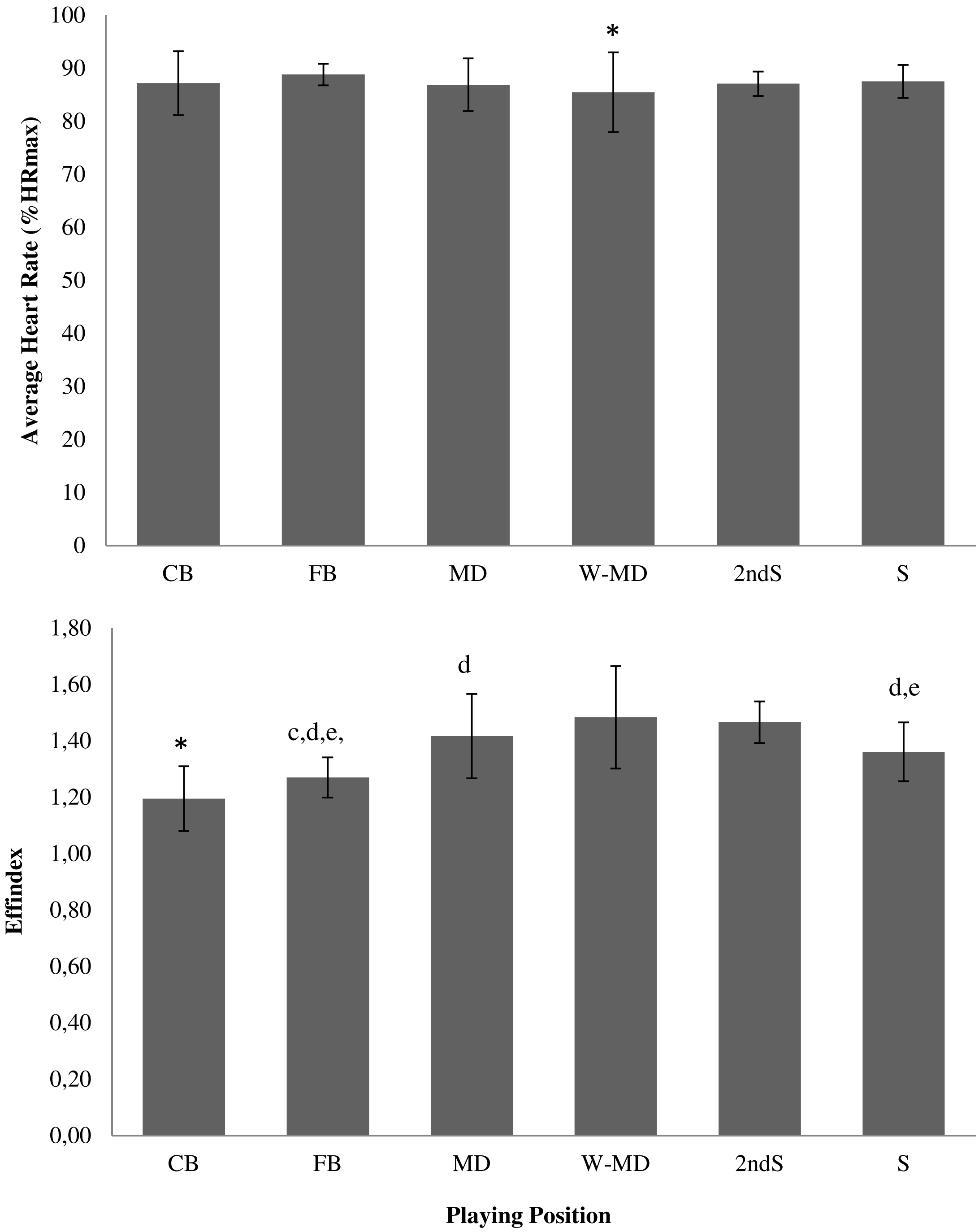

Figure 1. Average Heart Rate expressed in relation to the individual maximal HR (HR_{max}) and Effindex during the half in professional soccer players (*n* = 348). Data are mean ± SD.

CB: Centre Backs; **FB:** Full Backs; **MD**: Midfielders; **W-MD**: Wide Midfielders; **2^{ns}S**: Second Strikers; **S**: Strikers.

a: Significant difference *vs.* CB; **b**: Significant difference *vs.* FB; **c**: Significant difference *vs.* MD; **d**: Significant difference *vs.* W-MD; **e**: Significant difference *vs.* 2^{nd}S; **f**: Significant difference *vs.* S; *: Significantly smaller than any other group.

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Human Kinetics
ORIGINAL INVESTIGATION

Relationship Between External and Internal Loads of Professional Soccer Players During Full Matches in Official Games Using Global Positioning Systems and Heart-Rate Technology

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Purpose: To analyze the match running profile, distance traveled over successive 15 min of match play, heart rates (HRs), and index of performance efficiency (eff_{index}) of professional soccer players with a global positioning system (GPS) and HR in official competition. ***Methods:*** Twenty-six professional players were investigated during full matches in competitive club-level matches (N = 223). Time–motion data and HR were collected using GPS and HR technology. ***Results:*** The relative total distance was 113 ± 11 m/min, with substantial differences between halves. For all playing positions, a substantial decrease in total distance and distance covered at >13.0 km/h was observed in the second half in comparison with the first. The decrease during the second half in distance covered at >13.0 km/h was substantially higher than in total distance. The average HR recorded was 86.0% maximal HR, and the relationship between external and internal load (eff_{index}) was 1.3, with substantial differences between halves in all playing positions, except strikers for eff_{index}. Wide midfielders reflected substantially the lowest mean HR and highest eff_{index}, whereas center backs showed substantially the lowest eff_{index} of all playing positions. ***Conclusions:*** The current study confirmed the decrement in a player's performance toward the end of a match in all playing positions. Wide midfielders displayed the highest and fittest levels of physical and physiological demands, respectively, whereas center backs had the lowest and least-fit levels of physical and physiological demands, respectively. The position-specific relationship between external and internal load confirms that players with more overall running performance during the full match were the best in eff_{index}.

Keywords: team sport, time motion, football

Time-motion analysis, or player tracking, is commonly used by scientists to evaluate performance[1] and understand the training demands in team sports. A range of methods can be used to track and monitor players' activity profile and load during competitive games and training. Microtechnology devices that include global positioning systems (GPS) and other movement sensors are now widely used in practice in many sports to assess the external load for players, as it has been shown to provide a reliable and valid measure of the physical activity profile of team sports.[2] The internal load of players is commonly monitored using physiological and/or perceptual measures such as heart rate (HR) and rating of perceived exertion.[3] By describing the changes in relationships between internal and external loads during competition and training, it may be possible to understand the changes in player performance or fitness status. Few studies have examined both the internal and external loads of team-sport players during competition and training.[4–6]

Different technologies are used to monitor player activity profiles (ie, external loads) in training and competition, with GPS technology often used to monitor training while multiple camera semiautomatic systems are used in competition.[7] Limited research within soccer may possibly be attributed to the International Federation of Football Association prohibiting the use of GPS in professional competition matches. Therefore, although there have been many published reports of training activity profiles in soccer,[8] there is relatively little information on player activity profiles during competition with GPS devices.[5,9,10] Most reports from top-level soccer players have been derived from multiple camera semiautomatic systems.[11–14] The major benefit of GPS and HR technology within competition settings is the ability to provide real-time movement demand (eg, distance and speed) and internal load (HR) information of on-field players to coaches and compare easily the training drills data with the data from football matches using the same technology. The video footage cannot provide internal load information. In competition settings, the video footage is a time-consuming process that needs to take place for each individual player, making it impossible to provide real-time movement demand information. In addition, GPS technology enables further analysis of speed. A detailed understanding of match demands provides for the provision of individually tailored training programs that more accurately reflect competition demands and ensures players reach optimal training targets.

In an effort to better understand the demands of soccer in official games, studies using multiple camera systems have described the overall activity profiles and temporal changes in activity completed in different speed zones during match play.[11–14] Although some studies have reported no differences between halves,[12,15] most studies reported a decline in the total distances covered and high-intensity running in the second half compared with the first half.[11,13,14,16] Similarly, temporal reductions in the total distance and running distances covered at higher speeds in 15-minute periods of match play have been reported independent of the player position.[11,16,17]

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These changes in activity profile have been reported to be due to a combination of decrement of player performance and tactical adjustments. However, many of these studies are limited, as it is difficult to clearly identify the decrement of player performance in the absence of internal load information.

Only 1 study[5] has described the physical activity profiles of top professional soccer players during official competitions using GPS technology. Moreover, no data are currently available about the internal and external loads of professional soccer players during a full match in official games. The aim of this article is to examine the temporal changes (ie, 15-min periods) in the internal and external loads of top professional soccer players during match play. External (ie, distances traveled in various speed zones), internal (HR), and integrated measures of load (ie, the index of performance efficiency [eff_{index}]) of the various playing positions during official competitions will be described. Based on previous literature, our working hypothesis was the decrement of player performance toward the end of match.[11,16,17] We also hypothesized that the highest loads would be observed in wide-midfielders, whereas central defenders would show the lowest loads.[11–13,15]

Methods

Subjects

Twenty-six professional outfield players (27.3 ± 3.4 y, 180.4 ± 3.6 cm, 76.2 ± 6.8 kg) from the same team were investigated during competitive club-level matches in the national league, national cup, national super cup, and UEFA Europa League. All the players participated on average in ~14 hours of combined soccer (4–6 sessions), strength (1 or 2 sessions), specific training (1 session), and competitive play (1 or 2 games/wk) per week. All players were well accustomed to this training and competition load. Written informed consent was obtained from players before the investigation. The experimental protocol was approved by the institutional ethics committee of the University of Pablo de Olavide.

Experimental Procedures

An observational design was used to examine the internal and external loads of soccer players during competitive matches using GPS technology and HR response. Match analyses were performed 3 to 15 times on each player over a period of 2 seasons (N = 223 match files). Because of the high level of the opposing teams and the consistent format of the competition, match-by-match variability in running performance was likely reduced.[14] All matches were performed on outdoor natural grass fields using 11 players per side. Tactically, the team used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a "second striker." Because players' roles within the team structure changed little during the games analyzed, all players were assigned to 1 of 6 positional groups: center backs (CB, n = 44 files), fullbacks (FB, n = 47 files), midfielders (MD, n = 54 files), wide midfielders (W-MD, n = 26 files), second strikers (2nd S, n = 20 files) and strikers (S, n = 31 files). Playing time was 2 × 45 minutes, and only time–motion data of players who participated in the entire game were included for the subsequent analyses.

Activity Pattern Measurements

The players were required to wear a GPS unit (SPI Pro X; GPSports Systems, Canberra, Australia) during the game, which was fitted to the upper back (ie, between the shoulder blades) of each player using an adjustable neoprene harness. The data stored included HR, time, speed, and distance. GPS data were recorded at 5-Hz frequency and accelerometer data to 100 Hz. The validity and reliability of the GPS system have been previously reported[2,18] and used in soccer players.[5,8,19–21] The current system has been reported to be capable of measuring individual movement patterns in soccer.[22] To remove as much associated error as possible, researchers used the same devices on the same individuals when monitoring soccer players. None of the soccer fields used caused interferences in the GPS signal.

Match Running Demands Analysis

Time-motion data from all players were analyzed with the software designed (Team AMS-R1-2012-3; GPSports Systems) to provide objective measures of physical match performance (N = 223 files from 26 different players). The selected player activity ranges were adapted from previous studies with professional soccer players using GPS technology[5] as follows: total distance covered (TD), distance covered running above moderate speed (>13.0 km/h), and distance covered running above high speed (>18.0 km/h). For every 15-minute period, calculations were made of relative total distance traveled throughout the match.

Exercise Intensity

Match internal exercise intensity was quantified by monitoring HR during each game. HR was continuously measured with HR belts (Polar, Kempele, Finland) attached to their chests and was expressed in relation to the individual maximal HR ($\%HR_{max}$). The individual maximal HR was obtained throughout the latest Yo-Yo Intermittent Recovery Test[23] regularly assessed during the season or during the course of the match if the HR_{max} was higher than the value obtained from the field test.

Relationship Between External and Internal Load Measures

The eff_{index} for the quantification of the dose-response of the match stimulus was calculated as (velocity in $m \cdot min^{-1} \cdot \%HR_{max}^{-1}$) for every entire match.[5] This index integrates mean speed (ie, external load) with respect to the relative cardiovascular stress (ie, internal load) during the match play into a single parameter[24] and expresses how efficiently one can run with a given cardiovascular stress during a determined period (eg, 45 min). The eff_{index} has shown to be an appropriate tool for detecting differences in the physical profiles of elite professional soccer players at different playing positions during official games[5] and changes on the athletes' performance over the entire match.[24]

Statistical Analysis

Variables are reported as mean ± SD. All variables presented normal distribution (Shapiro-Wilk Test). The differences between the first and second halves of the match were determined using a Student's dependent t test for paired samples (90% confidence interval). A repeated-measures analysis of variance was used to determine differences in the distance covered in each speed zone and during each successive 15-minute period of match play. Significant differences were determined by a Bonferroni's post hoc test. Cohen's effect size (ES) was also calculated using the Hopkins' spreadsheets[25,26] to compare the magnitude of the differences between groups on certain variables,[27] and quantitative differences were assessed qualitatively[28] as the following: <1%, almost certainly not; 1%-5%, very unlikely; 5%-25%, unlikely; 25%-75%, possible; 75%-95%, probably; 95%-99%, very likely; and >99%, almost certain. A substantial effect was set at >75%.[29-31] If the chance of higher or lower differences was >75%, the true difference was assessed as clear (substantial). The SPSS statistical software package (V20.0 for Windows, SPSS Inc, Chicago, IL) was used for data analysis.

Results

Movement Analysis

The relative TD (± SD) covered during the match was 112.9 ± 10.6 m/min, with substantial differences between the first and second half (117.0 ± 10.4 vs 108.8 ± 10.7 m/min, respectively). As a percentage of this distance, 28% (31.3 ± 8.0 m/min) was running above medium speed (>13.0 km/h), with substantial differences between the first and second half (33.4 ±8.2 vs 29.3 ± 7.7 m/min, respectively), and 9.0% (10.0 ± 3.7 m/min) above high speed (>18.0 km/h) also with substantial differences between first and second half (10.7 ± 3.9 vs 9.4 ± 3.5 m/min, respectively). Differences between the first and second halves for intensity and load at each specific playing position are shown in Table 1 and Figure 1, respectively. All playing positions demonstrated a substantial decrease in TD and distance covered >13.0 km/h in the second half compared with the first (Table 1 and Figure 1). Nevertheless, the distance traveled above high speed (>18.0 km/h) was substantially reduced during the second half only in FB, MD, and S (Table 1 and Figure 1). The decrease during the second half in distance covered >13.0 km/h was substantially higher than in TD (–10.9% vs –6.9%, respectively).

Playing position significantly impacted on distance covered during the match (Table 1). Defenders covered the lowest TD, whereas W-MD and 2nd S covered the highest TD. MD covered a substantially greater TD than S during the first half, but not during the second. Defenders covered substantially lower distance >13

Table 1 Match Physical Activity Profile in Professional Soccer Players (N = 223, Mean ± SD)

	Total Distance Covered (m/min)		Distance Covered at >13 km/h (m/min)		Distance Covered at >18 km/h (m/min)	
Position	First half	Second half	First half	Second half	First half	Second half
CB (n = 45)	105 ± 8[a]	97 ± 10[a,b]	25 ± 6[a]	23 ± 5[a,b]	8 ± 3[a]	7 ± 2[a]
FB (n = 47)	113 ± 7[c,d,e,f]	105 ± 8[b,c,d,e,f]	30 ± 6[c,d,e,f]	27 ± 7[b,c,d,e,f]	10 ± 3[d,e,f]	9 ± 3[b,d,e,f]
MD (n = 54)	122 ± 6[d,e]	113 ± 6[b,d,e]	36 ± 7[d,e]	30 ± 6[b,d,e]	10 ± 3[d,e,f]	8 ± 3[b,d,e,f]
W-MD (n = 26)	127 ± 5	118 ± 6[b]	42 ± 5	39 ± 5[b]	15 ± 3	14 ± 2
2nd S (n = 20)	127 ± 6	118 ± 6[b]	42 ± 4	36 ± 5[b,d]	12 ± 2[d]	11 ± 3[d]
S (n = 31)	119 ± 9[c,d,e]	110 ± 10[b,d,e]	34 ± 6[c,d,e]	29 ± 6[b,d,e]	13 ± 3[d]	11 ± 3[b,d]

Abbreviations: CB, center back; FB, fullback; MD, midfielder; S, striker; 2nd S, second striker; W-MD, wide midfielder.

[a] Substantial difference from any other specific positions. [b] Substantially smaller than first half. [c] Substantial difference vs MD. [d] Substantial difference vs W-MD. [e] Substantial difference vs 2nd S. [f] Substantial difference vs S.

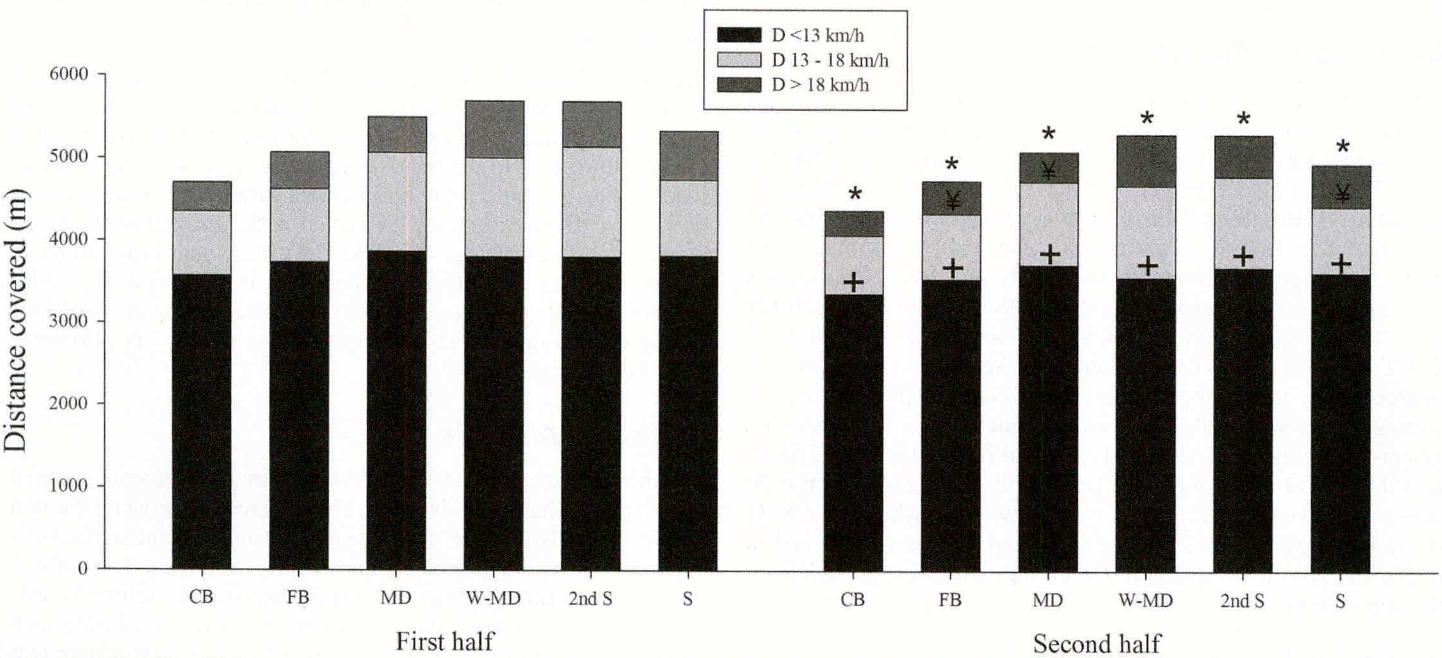

Figure 1 — Match running profile in professional soccer players (N = 223). *Substantial difference in total D vs first half. +Substantial difference in D > 13 km/h vs first half. ¥Substantial difference in D >18 km/h vs first half. Abbreviations: CB, center backs; D, distance covered; FB, fullbacks; MD, midfielders; S, strikers; W-MD, wide midfielders.

km/h, whereas W-MD and 2nd S traveled substantially the higher distance >13 km/h during the first half. The W-MD also traveled greater distance >13 km/h during the second half, but the 2nd S substantially reduced the distance traveled in this speed zone during this period. MD covered a substantially greater distance >13 km/h than S during the first half, but not during the second. CB covered substantially the lowest distance >18 km/h, whereas W-MD traveled the greatest distance. FB and MD covered substantially lower distance >18 km/h than S and 2nd S (Table 1).

Analysis of the distance traveled over successive 15-minute periods of match-play are shown in Table 2. The data revealed for all the playing positions a greater distance covered during the first 15 minutes compared with other periods of the match, with less distance traveled during the last 15 minutes compared with the periods of 0 to 60 minutes for CB, FB, MD, S, and with the periods of 0 to 75 minutes for W-MD and 2nd S (Table 2).

Internal Exercise Intensity

The mean HR during the match was 86.0% ± 4.9% HR_{max} with substantial differences between first and second half (87.0% ± 5.2% vs 85.0% ± 4.6% HR_{max}, respectively). Differences in HR response between halves for each specific playing position are shown in Table 1. During the second half, FB, 2nd S, and S substantially reduced their HR in comparison with the first half, whereas the mean HR in CB, MD, and W-MD remained stable throughout the whole match with no differences between halves (Table 3).

The HR responses of the various playing positions are shown in Table 3. Mean HR was lower in W-MD than any other playing position. During the first half, mean HR was substantially lower in the 2nd S than FB and S; and in MD than FB. During the second half, mean HR was lower in 2nd S compared with the CB, FB, and MD and in S rather than FB and MD.

Relationship Between External and Internal Load Measures

The eff_{index} during the match was 1.3 ± 0.2, with substantial differences between first and second half (1.4 ± 0.2 vs 1.3 ± 0.2, respectively). Differences between halves for each specific playing position are shown in Table 1. The eff_{index} was substantially reduced during the second half compared with the first in all of the playing positions, with the exception of S, in which there were no differences (Table 3).

Differences in eff_{index} between specific positions are shown in Table 1. W-MD had the substantially highest eff_{index}, whereas CB showed substantially the lowest. In addition, 2nd S presented substantially higher eff_{index} than FB, MD, and S, the same as S in regard to FB. The eff_{index} in MD was substantially higher than FB and S during the first half, but only in respect FB during the second half (Table 3).

Table 2 Relative Distance Traveled (m/min) Over Successive 15-Minute Periods of Match Play in Professional Soccer Players (N = 223, Mean ± SD)

	Periods of the First Half			Periods of the Second Half		
Position	0–15 min[a]	15–30 min[b]	30–45 min[c]	45–60 min[d]	60–75 min[e]	75–90 min
CB (n = 45)	110 ± 9	101 ± 9[a]	102 ± 10[a]	98 ± 18[a]	96 ± 18[a,c]	95 ± 17[a,b,c,d]
FB (n = 47)	119 ± 7	110 ± 11[a]	109 ± 10[a]	109 ± 10[a]	105 ± 10[a,b,c,d]	102 ± 11[a,b,c,d]
MD (n = 54)	129 ± 9	118 ± 8[a]	120 ± 11[a]	120 ± 10[a]	110 ± 9[a,b,c,d]	109 ± 9[a,b,c,d]
W-MD (n = 26)	133 ± 8	124 ± 9[a]	122 ± 10[a]	125 ± 8[a]	118 ± 11[a,b,c,d]	110 ± 13[a,b,c,d,e]
2nd S (n = 20)	136 ± 10	124 ± 8[a]	119 ± 14[a,b,d]	127 ± 9[a]	115 ± 7[a,b,d]	111 ± 11[a,b,c,d,e]
S (n = 31)	126 ± 10	115 ± 12[a]	117 ± 10[a]	115 ± 13[a]	108 ± 12[a,b,c,d]	107 ± 12[a,b,c,d]

Abbreviations: CB, center backs; FB, fullbacks; MD, midfielders; S, strikers; 2nd S, second strikers; W-MD, wide midfielders.

[a] Substantial difference vs 0- to 15-min period. [b] Substantial difference vs 15- to 30-min period. [c] Substantial difference vs 30- to 45-min period. [d] Substantial difference vs 45- to 60-min period. [e] Substantial difference vs 60- to 75-min period.

Table 3 Mean Heart Rate (%HR_{max}) and Eff_{index} in Professional Soccer Players (N = 223, mean ± SD)

	Heart Rate (%HR_{max})		Eff_{index} (Arbitrary Units)	
Position	First half	Second half	First half	Second half
CB (n = 45)	88 ± 6	86 ± 5	1.20 ± 0.1	1.14 ± 0.1[a]
FB (n = 47)	89 ± 2	87 ± 2[a]	1.27 ± 0.1[b]	1.21 ± 0.1[a,b]
MD (n = 54)	87 ± 6[c]	86 ± 3	1.42 ± 0.2[b,c,d]	1.32 ± 0.1[a,b,c]
W-MD (n = 26)	83 ± 8[e]	81 ± 6[e]	1.53 ± 0.2[e]	1.46 ± 0.2[a,e]
2nd S (n = 20)	87 ± 2[c,d]	84 ± 2[a,b,c,f]	1.46 ± 0.1[b,c,d,f]	1.41 ± 0.1[a,b,c,f]
S (n = 31)	88 ± 3	84 ± 6[a,c,f]	1.35 ± 0.1[b,c]	1.33 ± 0.2[b,c]

Abbreviations: HR_{max}, maximal heart rate; eff_{index}, index of performance efficiency; CB, center backs; FB, fullbacks; MD, midfielders; S, strikers; 2nd S, second strikers; W-MD, wide midfielders.

[a] Substantially smaller than first half. [b] Substantial difference vs CB. [c] Substantial difference vs FB. [d] Substantial difference vs S. [e] Substantial difference vs any other specific positions. [f] Substantial difference vs MD.

Discussion

The aim of this study was to quantify for the first time to our knowledge the internal and external loads of elite professional soccer players during full official matches using GPS and HR response. The main findings of the current study showed that (1) for all the playing positions, a substantial decrease in distance covered was reflected in the second half; (2) a greater distance was covered during the first 15 minutes compared with other periods of the match; (3) only 2nd S and S had a substantially reduced HR during the second half (remained unchanged in others); and (4) eff_{index} was substantially reduced in almost all the playing positions during the second half. In addition, playing position impacted substantially on relative distance covered at different speeds, and relationships between external and internal load among position-specific players showed that those with higher overall match activity profile had the highest eff_{index}.

The relative total distances covered in the current study (~113 m/min) were similar to those reported in semiprofessional soccer players[8] (113 m m/min) and higher than professional soccer players competing in the Australian League (A League)[15] (~104 m/min) and youth soccer players[32] (range 94-109 m/min). These results suggest that the elite European official games are played at a similar mean speed as semiprofessional soccer players during friendly matches.[8] However, accurate comparison between the present and this previous study is difficult due to methodological differences, because the previous study[8] had a small sample (ie, 27 recordings from 7 friendly matches) and included data from players who had relatively short match times (ie, >15 min). In contrast, in the current study, we only included player's data in the analysis if they played entire matches. Therefore, comparison of findings between these studies needs to be interpreted cautiously because it is likely that the longer the match duration, the lower the match speeds. Indeed, a previous study using GPS technology showed that in an overall match, elite European professional soccer players played 45 minutes (only first half) at ~119 m/min.[5]

The present results also showed a decrease in both TD and distance covered >13.0 km/h in the second half for all playing positions. The decline in movement patterns between halves is probably associated with the decrement of player performance,[1,16,33] although reductions in running performance also could be due to tactical demands or other match-related factors. Nonetheless, the reduced eff_{index} supports the presence of decrement of player performance as the player's relative distances traveled compared with the internal load response was reduced, but with differing magnitudes for the different playing positions (range from –3% in 2nd S to –7% in MD). The greatest decreases appeared in the distance covered >13 km/h, suggesting that decrements of distances covered at speeds above this threshold may be a more reliable indicator of decrement on performance in soccer players. Notably, however, not all of the playing positions reduced their running at high speed during the second half. This may be a sign of "pacing," in that players may modify their activities at lower speeds to preserve their capacities to exercise at higher speeds throughout the entire game.[34,35] Indeed, it has previously been shown that the ability to maintain high-intensity running (>18.0 km/h) is a crucial element of soccer performance[16] and may even be critical to the outcome of matches.[36] Previous studies reflected similar differences between first- and second-half activity profiles in professional top-class soccer players[1,16] using video analyses, and players in the English Premier League with less distance at high intensity covered during the first half were able to travel more distance in the second half.[14] Furthermore, it has also been shown that players with higher levels of decrement of performance have decreased involvements with the ball and a decrease in the total number of short passes and successful short passes during matches.[1]

This diminution in physical activity profile as the game progresses has also been demonstrated through a substantial reduction in the relative distance covered in the last 15-minute period of the match compared with the first 15 minutes (range–14% to –18%). Similar research findings was reflected by Mohr et al,[16] who used video match analyses to show that players from all playing positions showed a decrease in high-intensity running in 15-minute intervals toward the end of the match. These authors argue that most players in elite soccer tax their physical capacity during a game.[16] However, in the current study we observed that although the eff_{index} was substantially reduced in almost all players (with the exception of S), only half of the playing positions had a reduced activity profile in the higher speed zone.

Although the data of our study are novel, there are limitations that should be acknowledged. First, our sample size was relatively small, with different numbers of players among some playing positions, and only included data from a single team. Therefore, the results of this study may be specific to these team players and to the planning adopted by the coaching staff, including a possible bias toward the tactical formation (4-4-1-1) used for the team that was assessed. The participating team was competing at the second-highest standard of soccer competition in Europe. Consequently, further studies involving a greater number of participating teams are warranted to establish more representative results. Another limitation is that GPS has shown to be a valid method for measurement of distance traveled at low to moderate but not high speeds.[37] The reliability of GPS decreases with the increased velocity of movement. Therefore, caution must be taken when interpreting individual movement demands performed at highest velocities. An increased sample rate could improve the reliability and validity of GPS devices. Consequently, more studies with currently available GPS systems recording at increased sample rate are required to replicate our findings and improve the reliability and validity of the results. Although research has shown GPS to be a valid and reliable measure of team sport athlete movement demands in a controlled environment,[38] more studies under realistic conditions must be replicated in soccer players to support the ecological validity of GPS and HR technology in movement demands. Studies adding physical performance assessments, using relative intensity zones and analyzing high-intensity running activity (accelerations, decelerations, impacts) during official games and considering tactical elements, and situational and interactional contexts (ie, game location, game result, quality of opposition) are imperative.

Practical Applications and Conclusions

This study confirmed the research hypothesis of decrement in player performance toward the end of the game in all playing positions. It also confirmed that W-MD performed the highest physical and physiological demands, respectively, whereas CB performed the lowest physical and physiological demands, respectively. The position-specific relationship between external and internal load measures in this study confirms that players with more overall running performance during the full match (W-MD and 2nd S) presented the higher values in eff_{index}.

Coaches, practitioners, and sports scientists working within top professional soccer players should be aware of the physical and physiological demands associated with the competition. Findings obtained from monitoring internal and external loads assessed in this study may be used to provide a stronger understanding of the specificity of training and drill design. Indeed, training activities should focus on the level of physical and physiological demands of players during the matches. Many training drills can elicit similar internal loads (HR-based) compared with actual match play, providing an optimum training physiological stress. However, these drills may elicit an inappropriate external load in comparison with the movement patterns that players perform during the match according to the specific game model. As an alternative, physical training activities can be designed to replicate the position-specific demands observed in this study. Ideally, each team should have its own physiological and mechanical demands associated to soccer match play during official games, measured with the same technology that these players are monitored during training sessions (ie, GPS-HR).

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Variability of GPS-derived running performance during official matches in elite professional soccer players

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ABSTRACT

BACKGROUND In this study, the between match running performance variability was assessed in soccer players.

METHODS GPS-derived data from nineteen elite soccer players were collected over two consecutive seasons. Time-motion data for players with more than five full-match were analyzed (n=202). Total distance covered (TD), TD >13-18 km/h, TD >18-21 km/h, TD >21 km/h, number of acceleration >2.5-4 m.s^{-2} and >4 m.s^{-2} were calculated. The match-to-match variation in running activity was assessed by the typical error expressed as a coefficient of variation (CV,%) and the magnitude of the CV was calculated (effect size).

RESULTS When all players were pooled together, CVs ranged from 5% to 77% (first half) and from 5% to 90% (second half) for TD and number of acceleration >4 m.s^{-2} and the magnitude of the CVs were rated from small to moderate (effect size = 0.57-0.98). The CV was likely to differ between playing positions (e.g., TD >13-18 km/h 3.4% for second strikers vs 14.2% for strikers and 14.9% for wide-defenders vs 9.7% for wide-midfielders).

CONCLUSIONS Present findings indicate that variability in players' running performance is high in some variables and likely position-dependent. Such variability should be taken into account when using these variables to prescribe and/or monitor training intensity/load.

Key words: monitoring, football players, worthwhile changes, playing position

Introduction

During the past decade, match running performance monitoring has become common practice in professional soccer players [1]. The detailed analysis of the match running activity is likely important to profile the individual physical demands, which can be used to define and prescribe tailored training sessions targeting players' game and playing position requirements [2,3].

Variability of the locomotor activity during matches (i.e., degree of change in a particular index when repeated on different occasions in similar conditions, as evidenced by the coefficient of variation (CV) of a measurement) is of great importance for sports scientists and coaches to avoid bias interpretation when assessing changes/differences in a game or training outcome. Half of a CV, for example, is thought to represent a minimal threshold needed to assess a meaningful difference (between-group comparisons) or change (training studies), or the so called "smallest worthwhile difference / change" [4].

Limited data on the match-to-match variation in physical performance in soccer exist [5,6]. Analyzing data obtained from a camera-based tracking system, a 5% CV for distances covered >14.4 km/h and 14.4% - 16% CV for distances covered >19.8 km/h have been reported [5,6]. Generally, training data is obtained using a global positioning system (GPS) and the interchangeability between camera-based and GPS is somewhat difficult as these systems are likely to provide different data for the same variables making the comparison of the physical performance obtained from the matches and trainings difficult [7]. A logical consensus in sport science is that the most effective training for preparing players for competition is to closely replicate and overload the competitive performance requirements/demands. Therefore, training prescriptions in soccer should take into account the players' game demands for the different playing position [2]. Therefore, assessing the variability of the running performance from GPS-derived data in professional soccer players during official games would be of great interest to compare and interpret the data arising from soccer training in comparison with game demands.

Despite the growing use of GPS devices in elite football, and the statement of the FIFA® allowing the use of this technology during the official matches, to date no match-to-match variability on running performance during official games is available. Therefore, the aim of this study was to assess the match-to-match variability obtained using GPS devices, collected during official games in professional soccer players.

Materials and methods

Participants

Time-motion analysis of running activity was collected in 19 professional soccer players (age: 27.1 ± 3.3 yrs; height: 180.7 ± 3.2 cm and body mass: 76.0 ± 6.6 kg). All the players participated on average in ~ 14h of combined soccer (4-6 sessions), strength (1-2 sessions), specific training (1 session) and competitive play (1-2 games per week) per week. The players gave a written informed consent. The experimental protocol was approved by the local Institutional Ethics Committee of the University of Pablo de Olavide (Master de Fútbol, Research Department), and have been conducted according to the principles expressed in the Declaration of Helsinki.

Design

An observational design was used to examine the physical demands and exercise intensity in male soccer players during competitive matches using GPS technology. Nineteen outfield players from the same team were investigated during competitive club level matches in the national league, national cup, national super cup and UEFA Europa League. Match analyses were performed 5-28 times on each player over a period of two seasons (n = 202). All matches were performed on outdoor natural grass fields using 11 players per side. Tactically, the team used a 4-4-1-1 formation, a variation of 4-4-2 with 1 of the strikers playing as a "second striker". Since players' roles within the team structure changed little during the analyzed games, all players were assigned to 1 of 6 positional groups: central-defender (3 players, 38 files with 13, 7, and 18 files for the three different players, respectively), wide-defender (5 players, 47 files with 14, 14, 6, 7 and 6 files for the different 5 players, respectively), central-midfielder (3 players, 50 files with 16, 28 and 6 files for the three different players, respectively), wide-midfielders (3 players, 23 files with 8, 5 and 10 files for the three different players, respectively), second strikers (2 players, 17 files with 5 and 12 files for the two different players, respectively) and strikers (3 players, 27 files with 5,17 and 5 files for the three different players, respectively). Only data from players with full-match data set were analyzed. Playing time was 2 x 45 min plus additional time. The data from each half were re-calculated to 45 min to avoid discrepancies in the playing time due to different additional time.

Activity pattern measurements

During each match a global positioning system unit (SPI Pro X, GPSports, Canberra, Australia) recording at 5 Hz (interpolated to 15 Hz) was fitted to the upper back of each player using an adjustable neoprene harness. A good accuracy was reported for the assessment of total distance (typical error of the estimate; TEE: 0.4-3.7%), a slightly higher CV for high speed running distance (7.5%) and a higher CV for very high speed running (23.2%) [8]. The measure of peak speed presented a relatively low TEE (3.3%) and very high intraclass correlation coefficient ($r = 0.92$) [7]. A TEE of 3.7% and a CV of ≈ 16% was reported maximal acceleration [7]. More details on the validity and reliability of the system used are provided elsewhere [8]. To reduce the variability an exclusive GPS unit was allocated for each player during all games [9]. For the analyzed games, the number of satellites for GPS was satisfactory 8-12, average 10.5 ± 2. The horizontal dilution of position (HDOP), which is a reflection of the geometrical arrangement of satellites and is related to both the accuracy and quality of the signal was not collected, which is a limitation.

Match running demands analysis

Computed running activity included: 1) total distance covered (TD, m), 2) distance covered between 13-18 km/h (m), 18-21 km/h (m), >21km/h (m), 3) number of acceleration between 2.5-4 $m.s^{-2}$ and >4 $m.s^{-2}$ 4) number of efforts >21 km/h and 5) peak speed attained during the match (km/h).

Statistical analysis

Variables are reported as CV with 90% confidence intervals (90%CI). We used a specifically designed spreadsheet [10] to assess the between-matches variability in running performance in this spreadsheet, all analyses are performed on log-transformed data, which substantially reduce non-uniform errors. The coefficient of variation (CV, %) (i.e., the typical error expressed as a percentage of the mean score) was calculated for an easier comparison with the literature. The magnitude of the CV for the different running performance variables were expressed as standardized differences in the mean (effect size, ES), moreover the magnitude of the differences between first and second half CV was also calculated. The magnitude of the standardized differences was interpreted using Hopkins threshold: >0.2 (*small*), >0.6 (*moderate*), >1.2 (*large*) and > 2.0 (very *large*) [11]. Confidence intervals (90%) for the (true) within/between-group differences were estimated [11]. If the 90% confidence intervals overlapped small positive and negative values, the magnitude was deemed unclear; otherwise that magnitude was deemed to be the observed magnitude [11].

Results

The CV% and the standardized differences of the physical performance measurements are reported in the Table 1, 2 and 3. When all players were pooled together, CVs for the first half ranged from 5% for TD to ≈ 77% for number of acceleration >4 $m.s^{-2}$ and the magnitude of the CVs were rated from small to moderate (ES = 0.51- 0.98). High speed running activity (i.e., total distance covered at speeds 13-18 km/h, 18-21 km/h and >21 km/h) showed a small-to-moderate CV in the first (i.e., 13%-43%; ES = 0.51-0.71) and second half (i.e., 17%-53%; ES = 0.58-0.73) (Table 1). The CV was likely to increase with the running speed zones 13.3% (11.6;15.8) vs 42.9% (34.9;48.9) for distance covered 13-18 km/h vs >21 km/h, respectively for distance covered between 13-18 km/h and distance covered >21 km/h, respectively Lower CV were observed for low acceleration compared with the high acceleration zones (e.g., 16.3% (14.2;19.3) vs. 76.8% (65.3;95.3) for the number of accelerations 2.5-4 $m.s^{-2}$ vs > 4 $m.s^{-2}$, respectively).

*******Table 1 near here*******

Playing position had an effect on CV (Table 2 and 3). For example, CV for TD >13-18 km/h ranged from 3.4% for second strikers to 14.2% for strikers and the magnitude of the CVs were rated as small (ES = 0.41- 0.48) and 14.9% for wide-defenders vs 9.7% for wide-midfielders and the magnitude of the CVs were rated as moderate (ES = 0.79- 0.80). Moreover, for peak speed CV ranged from 2.7% for second strikers to 10.1% for strikers and the magnitude of the CVs were rated as moderate (ES = 0.71- 1.15) and 5% for wide-defenders vs 3.7% for wide-midfielders and the magnitude of the CVs were small to moderate (ES = 0.51- 0.85).

********Table 2 and 3 near here ********

Discussion

This study examined for the first time the match-to-match variation of physical performance in professional soccer players during official soccer matches over two consecutive season using GPS technology. Our results show that 1) match-to-match CV ranged from 5.3% to 70% for the different locomotor variables, 2) the CVs were likely to increase with running/acceleration intensity and 3) CVs were differently affected by playing position.

The total distance was the most stable variable for all playing positions with a CV ranging from 3.5-5.5% for the first half and 3.0-8.2% for the second half, with an unclear difference between the first and the second half (Table 1-3). These results are in line with previous observations using camera-based tracking systems reporting a smaller CV for total distance compared with other running distance variables [5]. The CV was likely to increase with the running speed zones CV= 13.3% and 42.9% for distance covered between 13-18 km/h and distance covered >21 km/h, respectively. This is in line with previous observations using camera-based tracking systems [5,6] showing that higher speed running zones were likely to present a greater variability compared with the lower speeds. In the present study, the GPS-derived CV values obtained for distances covered at different speed bands are likely to represent game-related changes in running demands as the reported between-unit variation during a standardized task ranged from 2% (TD >14.4 km/h) to 6% (TD >25.1 km/h) [9].

In the present study, we present for the first time GPS-derived data related to the variability of accelerations obtained during official games in elite professional soccer players. Similar to the distance covered at different speeds, the number of accelerations performed at high accelerations was more variable than the number of low accelerations. In line with our results, Akenhead et al. [12] reported a greater CV for high magnitude accelerations (4 $m.s^{-2}$) compared with lower magnitude accelerations (2-3 $m.s^{-2}$) (47% vs. 3.1%, respectively) in standardized tasks. Similarly, between-unit variability increased with higher accelerations (e.g., 31% vs 43%) during a standardized task [9]. The relatively high CV scores reported for accelerations in the present study and elsewhere [9,12] would suggest that practitioners should be careful when interpreting acceleration-derived indices to monitor game / training physical performance. Similarly, the match-to-match variability of peak speed reached in the game (CV = 6%-10%; ES = 0.49-1.15) was 3- to 10-fold higher than the reported reliability (i.e., 1% to 2.3%) of this variable using GPS devices [9,13]. This small-to-moderate between games variability in the peak speed would indicate that the soccer players are likely to reach regularly high peak speed in the games and would suggest that soccer players should be physically prepared for this [14-17]. Alongside with the between unit-variability, this greater game-related variability is likely related with different factors such as physical and mental fatigue, pacing, and changes in tactical roles and playing styles associated with opponent player/team which affect the interaction of the player with the actual environment [14,18,19].

We provided, also for the first time, detailed GPS-derived match-to-match variability data on specific playing positions (Table 2 and 3). Similar to a previous report [6], we found likely between-position differences in CV for some variables. For example, wide midfielder showed a smaller CV compared with central midfielder for the distance covered between 13-18 km/h (10.4% vs 21.4%) and the peak speed reached (3.7% vs 6.4%) during the game. These differences in match-to-match variability between the different playing position is likely multifactorial and could be associated with the different between game demands (i.e., fatigue pacing strategies, and changes in tactical roles associated with opponent) [19]. Thus, for a more detailed assessment of locomotor performance, position specific CVs are recommended.

The relatively high CVs reported for high-speed locomotor variables have important implications for assessing and interpreting match/training physical performance and monitoring training load in soccer players. For example, the high match-to-match variability reported for players' high-speed locomotor activities suggests that players do not consistently produce their maximal efforts within games. As such, match-related high-speed locomotor performance might not be a good indicator of player's physical performance [20]. Moreover, because the CV value is typically higher than the calculated for the "smallest worthwhile change/difference", the ability to detect small, moderate or even large real changes/differences in player's high-speed locomotor performance can be compromised [21].

For example, the thresholds for small, moderate and large (0.2, 0.6 and 1.2 x between-subject SD, respectively) differences in the number of accelerations >4 $m.s^{-2}$ in a CD are 9.3%, 27.9% and 55.8% (data computed from Table 2). Because the CV for this particular playing position and variable was much higher (i.e., 94.4%), the responsiveness of that variable needs to be quite high before likely worthwhile changes/differences might be detected. While reliability, and associated usefulness parameters are important aspects to consider when monitoring and assessing players' performance, responsiveness is considered the most essential property of an evaluative instrument [22]. That is, the ability to detect practically useful changes over a particular time frame is what ultimately should determine the practical usefulness of a performance measure. It is also worthwhile indicating that the use of the GPS during soccer games could be problematic in stadium with high rise stands or over hanging stands which could weaken the signal resulting in poor data accuracy.

Conclusions

In conclusion, GPS-derived match-to-match variability in official games' locomotor performance of professional soccer players is high, particularly for high-speed variables, due to the complexity of match running performance and its most influential factors and reliability of the devices [3,19]. Moreover, playing position can affect the magnitude of such variability. An awareness of that variability associated with that variables typically employed to prescribe and/or monitor training intensity/load appears crucial before practitioners can use this data to support performance enhancement strategies.

Manipulation of training contents to optimize competitive performance is at the core of training monitoring and prescription in soccer. As such, a detailed knowledge of the match running demands can help in designing soccer-specific drills that meet player's needs [2]. In this regard, training load monitoring during training in soccer players frequently includes the quantification, via GPS devices, of high-intensity running actions such as high-speed running and/or accelerations [23]. Therefore, the knowledge of typical variation from game-to-game of the locomotor variables of interest is pivotal to evaluate real changes/differences in match play and training intensity and load. This would eventually facilitate effective planning and timing of subsequent training and recovery sessions to ensure the required physiological stimuli is applied.

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Table II. Between match variation of physical running performance, (Playing positions).
Table III. Between match variation of physical running performance, (Playing positions).

Table 1. Between match variation of physical running performance.

All pooled	Half 1	CV%	Standardized differences	Half 2	CV%	Standardized differences
Total distance (m)	5262.1 ± 460.9	5.3 (4.6;6.2)	0.57 (0.51;0.67)	4889.4 ± 481.9	5.17 (5.0;6.7)	0.59 (0.52;0.69)
D 13-18 km/h (m)	1015.8 ± 243.6	13.3 (11.6;15.8)	0.51 (0.45;0.59)	891.8 ± 224.5	17.4 (15.2;20.6)	0.58 (0.51;0.67)
D 18-21 km/h (m)	269.5 ± 83.3	21 (18.2;24.9)	0.60 (0.52;0.70)	235.2 ± 80.4	22.5 (19.5;26.7)	0.61 (0.54;0.72)
D >21 km/h (m)	211 ± 109.9	42.9 (36.9;51.8)	0.71 (0.62;0.83)	186.2 ± 95.6	53.0 (45.4;64.4)	0.73 (0.64;0.85)
# of Acc 2.5-4 (m/s/s)	56.3 ± 11.6	16.3 (14.2;19.3)	0.69 (0.61;0.81)	47.9 ± 10.9	18.1 (15.8;21.5)	0.69 (0.61;0.81)
# of Acc >4 (m/s/s)	4.6 ± 2.5	76.8 (65.3;95.3)	0.98 (0.86;1.15)	3.8 ± 2.2	89.7 (76.0;112.5)	0.98 (0.86;1.15)
# of efforts >21 (km/h)	11.7 ± 6	44.5 (38.3;53.8)	0.72 (0.64;0.85)	10.7 ± 5.1	49.0 (42.0;59.4)	0.73 (0.64;0.86)
Peak Speed (km/h)	29.0 ± 2.7	6.0 (5.2;7.0)	0.71 (0.62;0.83)	28.6 ± 2.4	7.7 (6.7;9.0)	0.87 (0.77;1.02)

Data are presented as mean ±SD or mean (90% confidence interval). D: Distance, #: number, Acc: accelerations, CV%: Coefficient of variation.

Table 2. Between match variation of physical running performance.

	Variables	Half 1	CV%	Standardized differences	Half 2	CV%	Standardized differences
Central Defender	Total distance (m)	4700.5 ± 351.2	5.0 (3.7;9.6)	0.68 (0.51;1.29)	4363.3 ± 477.5	4.5 (3.4;8.8)	0.49 (0.37;0.94)
	D 13-18 km/h (m)	783.6 ± 156.2	12.1 (8.9;24.2)	0.64 (0.48;1.21)	708.8 ± 168.9	16.3 (11.9;33.2)	0.68 (0.51;1.30)
	D18-21 km/h (m)	203.3 ± 66.6	26.2 (18.9;55.5)	0.91 (0.68;1.72)	180.3 ± 59.7	13.8 (10.1;27.7)	0.58 (0.43;1.10)
	D >21 km/h (m)	154.6 ± 92.1	51.2 (36.0;119.0)	0.91 (0.68;1.73)	124.7 ± 58.4	85.3 (58.3;222.1)	0.91 (0.68;1.72)
	# of Acc 2.5-4 (m/s/s)	55 ± 9.8	11.6 (8.5;23.1)	0.64 (0.48;1.21)	48.9 ± 9.9	13.9 (10.2;28.0)	0.63 (0.47;1.19)
	# of Acc >4 (m/s/s)	4.5 ± 2.1	90.4 (61.5;239.4)	1.16 (0.86;2.20)	4.1 ± 1.8	38.1 (27.2;84.6)	0.65 (0.48;1.23)
	# of efforts >21 (km/h)	8.3 ± 4.4	60.1 (42.0;144.3)	0.93 (0.69;1.76)	7.1 ± 3	69.0 (47.8;170.6)	0.84 (0.63;1.59)
	Peak Speed (km/h)	28 ± 2.9	5.9 (4.3;11.4)	0.49 (0.37;0.93)	28.5 ± 2.3	7.3 (5.4;14.3)	0.73 (0.55;1.39)
Wide defenders	Total distance (m)	5068.3 ± 307.5	5.5 (4.3;8.2)	0.81 (0.64;1.19)	4732.2 ± 346.8	8.2 (6.4;12.2)	0.89 (0.71;1.31)
	D 13-18 km/h (m)	889.9 ± 159.4	14.9 (11.6;22.6)	0.79 (0.62;1.16)	800.8 ± 179.9	21.5 (16.7;33.1)	0.71 (0.56;1.04)
	D 18-21 km/h (m)	240.7 ± 70.8	20.0 (15.5;30.6)	0.60 (0.47;0.87)	212.7 ± 70.7	27.8 (0.57;43.3)	0.72 (0.57;1.05)
	D >21 km/h (m)	203 ± 97.7	42.5 (32.3;68.0)	0.72 (0.57;1.05)	179.1 ± 82.5	37.2 (28.4;58.9)	0.61 (0.48;0.90)
	# of Acc 2.5-4 (m/s/s)	50.7 ± 9.3	15.7 (12.2;23.8)	0.73 (0.58;1.07)	44.5 ± 9.5	22.5 (17.4;34.6)	0.90 (0.71;1.31)
	# of Acc >4 (m/s/s)	4.2 ± 2.1	68.8 (51.2;115.5)	0.87 (0.69;1.28)	3.4 ± 1.7	91.2 (66.9;158.6)	1.05 (0.83;1.53)
	# of efforts >21 (km/h)	11.1 ± 5	52.5 (39.6;85.6)	0.83 (0.65;1.21)	10.6 ± 4.5	31.2 (23.9;48.8)	0.57 (0.45;0.83)
	Peak Speed (km/h)	29.3 ± 1.9	5.0 (4.0;7.5)	0.85 (0.67;1.24)	28.5 ± 2.5	9.3 (7.3;13.9)	1.04 (0.82;1.52)
Central midfielders	Total distance (m)	5476.9 ± 264.3	3.5 (2.4;6.9)	0.83 (0.59;1.63)	5066.4 ± 277.6	3.0 (2.1;6.1)	0.81 (0.57;1.59)
	D 13-18 km/h (m)	1170.1 ± 166.7	7.4 (5.2;15.2)	0.64 (0.46;1.26)	987.3 ± 162.6	14.2 (9.9;29.9)	0.73 (0.52;1.43)
	D 18-21 km/h (m)	265.1 ± 73	21.4 (14.7;46.5)	0.68 (0.48;1.33)	214.2 ± 62.7	26.1 (17.9;57.8)	0.64 (0.46;1.26)
	D >21 km/h (m)	146.1 ± 76.8	44.4 (29.8;106.2)	0.82 (0.58;1.61)	131.8 ± 63.6	88.7 (56.9;249.2)	1.14 (0.81;2.24)
	# of Acc 2.5-4 (m/s/s)	54.2 ± 9.3	20.4 (14.1;44.2)	1.10 (0.78;2.16)	43.7 ± 7.4	15.6 (10.8;33.0)	0.70 (0.50;1.38)
	# of Acc >4 (m/s/s)	3.4 ± 2.1	82.0 (53.3;277.1)	1.14 (0.81;2.52)	2.7 ± 1.7	174.8 (105.6;1293.3)	1.21 (0.86;3.15)
	# of efforts >21 (km/h)	8.3 ± 4.2	40.6 (27.4;95.6)	0.81 (0.57;1.59)	8 ± 3.6	83.0 (53.5;228.7)	1.25 (0.89;2.47)
	Peak Speed (km/h)	27.6 ± 2.4	6.4 (4.5;13.1)	0.78 (0.56;1.54)	27.3 ± 2	7.0 (5.0;14.3)	1.07 (0.76;2.10)

Data are presented as mean ±SD or mean (90% confidence interval). D: Distance, #: number, Acc: accelerations, CV%: Coefficient of variation.

Table 3. Between match variation of physical running performance.

	Variables	Half 1	CV%	Standardized differences	Half 2	CV%	Standardized differences
Wide midfielders	Total distance (m)	5684.8 ± 231.6	3.6 (2.5;6.6)	0.91 (0.65;1.66)	5298.4 ± 266.7	3.9 (2.8;7.2)	0.72 (0.51;1.30)
	D 13-18 km/h (m)	1191.4 ± 152.8	9.7 (6.8;18.3)	0.80 (0.57;1.45)	1117.3 ± 181.6	14.8 (10.4;28.5)	0.79 (0.56;1.43)
	D 18-21 km/h (m)	352 ± 67	10.4 (7.3;19.6)	0.46 (0.33;0.84)	330.3 ± 51.8	10.1 (7.1;19.1)	0.71 (0.51;1.29)
	D >21 km/h (m)	335.7 ± 91.1	38.9 (26.3;81.4)	1.21 (0.86;2.20)	293.1 ± 79.1	25.6 (17.6;51.1)	0.99 (0.70;1.79)
	# of Acc 2.5-4 (m.s-2)	72.1 ± 9.7	8.7 (6.2;16.4)	1.17 (0.83;2.12)	61.0 ± 11.0	15.6 (10.9;30.0)	0.94 (0.67;1.70)
	# of Acc >4 (m.s-2)	7.1 ± 3	82.6 (53.5;198.2)	1.02 (0.72;1.84)	5.8 ± 2.4	39.3 (26.6;82.4)	0.92 (0.66;1.67)
	# of efforts >21 (km/h)	18.6 ± 4.8	37.8 (25.6;78.9)	1.23 (0.88;2.24)	16.2 ± 3.2	18.8 (13.0;36.7)	0.96 (0.68;1.74)
	Peak Speed (km/h)	31.0 ± 2.5	3.7 (2.6;6.9)	0.51 (0.36;0.93)	30.0 ± 2.0	5.4 (3.8;10.1)	0.84 (0.60;1.53)
Second strikers	Total distance (m)	5690.7 ± 289	3.0 (1.9;15.4)	1.07 (0.68;5.21)	5306.8 ± 292.3	6.0 (3.8;33.1)	1.06 (0.68;5.17)
	D 13-18 km/h (m)	1338.5 ± 142.4	3.4 (2.2;17.8)	0.41 (0.26;2.02)	1093.9 ± 142.2	14.2 (8.9;91.5)	1.00 (0.64;4.90)
	D 18-21 km/h (m)	339 ± 56.1	14.0 (8.8;90.0)	1.17 (0.75;57.00)	309 ± 75.4	10.6 (6.6;63.3)	0.67 (0.43;3.27)
	D >21 km/h (m)	212.2 ± 71.8	21.3 (13.2;157.3)	0.82 (0.52;4.00)	216 ± 82.5	43.1 (25.7;475.7)	0.96 (0.61;4.69)
	# of Acc 2.5-4 (m.s-2)	62.9 ± 12.4	30.2 (18.4;263.8)	0.72 (0.46;3.49)	53.9 ± 10.5	17.0 (10.6;115.4)	0.65 (0.41;3.17)
	# of Acc >4 (m.s-2)	5.3 ± 2.4	68.2 (39.4;1168.0)	1.12 (0.72;5.50)	4.7 ± 3	61.1 (35.7;929.3)	1.23 (0.79;6.01)
	# of efforts >21 (km/h)	12.2 ± 4.7	7.1 (4.5;39.6)	0.39 (0.25;1.91)	12.9 ± 4.5	36.0 (21.7;348.6)	0.86 (0.55;4.20)
	Peak Speed (km/h)	28.8 ± 2.3	2.7 (1.7;13.8)	0.71 (0.45;3.46)	28.9 ± 2.5	6.3 (4.0;34.6)	0.91 (0.58;4.45)
Strikers	Total distance (m)	5330.6 ± 401.6	4.8 (3.4;13.0)	0.83 (0.59;2.17)	4934.5 ± 464.2	6.4 (4.5;13.1)	0.57 (0.41;1.13)
	D 13-18 km/h (m)	914 ± 183.1	14.2 (10.0;41.80	0.48 (0.34;1.25)	800.8 ± 191.9	22.6 (15.7;49.8)	0.71 (0.51;1.40)
	D 18-21 km/h (m)	298.8 ± 65.7	10.7 (7.6;30.7)	0.58 (0.42;1.53)	254.1 ± 66.1	23.9 (16.5;52.9)	0.72 (0.52;1.43)
	D >21 km/h (m)	303.7 ± 81.9	23.6 (16.5;74.5)	0.92 (0.66;2.41)	263.5 ± 86.7	35.0 (23.9;81.2)	0.88 (0.63;1.75)
	# of Acc 2.5-4 (m.s-2)	53.5 ± 8	19.0 (13.3;57.9)	0.91 (0.65;2.38)	44.4 ± 9.4	17.7 (12.3;38.1)	0.67 (0.48;1.33)
	# of Acc >4 (m.s-2)	4.7 ± 2	63.6 (42.5;264.4)	1.16 (0.83;3.05)	3.8 ± 2.2	74.9 (49.1;203.2)	0.92 (0.66;1.82)
	# of efforts >21 (km/h)	17.1 ± 5	26.2 (18.2;84.2)	0.77 (0.55;2.02)	14.5 ± 4.9	42.5 (28.8;101.8)	0.92 (0.66;1.82)
	Peak Speed (km/h)	30.5 ± 2.7	10.1 (7.1;23.9)	1.15 (0.82;2.56)	29.9 ± 2	5.0 (3.6;10.2)	0.83 (0.60;1.65)

Data are presented as mean ±SD or mean (90% confidence interval). D: Distance, #: number, Acc: accelerations, CV%: Coefficient of variation.