Universidad de Granada

Facultad de Ciencias de la Actividad Física y del Deporte

Departamento de Educación Física y Deportiva

Tesis Doctoral

Programa de Doctorado en Ciencias de la Educación

MONITORIZACIÓN Y CUANTIFICACIÓN DE LA CARGA DE ENTRENAMIENTO Y COMPETICIÓN EN FUTBOLISTAS DE ALTO NIVEL Y SU APLICACIÓN PRÁCTICA EN EL DISEÑO DE TAREAS.

Bernardo Guerrero Calderón

Dirigida por: Dr. Alfonso Castillo Rodríguez

GRANADA 2021

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'El gran objetivo de la educación no es el conocimiento, sino la acción'

Herbert Spencer

A mi Padre,
con quien tanto fútbol he compartido
y que seguro estará orgulloso de este trabajo.

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A lo largo de este trabajo hablo del sistema complejo que es el fútbol. Usando esta misma analogía, considero la vida como un sistema hiper-complejo en el que existe una conexión entre multitud de factores para la consecución de un objetivo. Por ende, todas aquellas personas que forman parte de mi vida, o que formado parte en algún momento, han contribuido de alguna manera en la realización de esta Tesis, y en definitiva que me convierta en quien soy. Gracias.

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I. Abreviaturas

Abreviaturas

ACCs	– número aceleraciones (≥2 $m \cdot s^{-2}$ en un intervalo de tiempo ≤0.5 seg.)
A:C WL ratio	– relación carga aguda: crónica
DECs	– número de desaceleraciones (≤ –2 $m \cdot s^{-2}$ en un intervalo de ≤0.5 seg.)
EDI	– índice de distancia equivalente, en porcentaje
EqD	– distancia equivalente, en metros
FC	– frecuencia cardiaca
GPS	– sistema de posicionamiento global
HIRD	– distancia total alta intensidad, a velocidades >14 $km \cdot h^{-1}$, en metros
HSRD	– distancia recorrida a alta velocidad (18-21 $km \cdot h^{-1}$), en metros
LSRD	– distancia recorrida a baja velocidad (<14 $km \cdot h^{-1}$), en metros
MD	– día de partido
ML	– carga de partido
MP	– potencia metabólica media, en $W \cdot kg^{-1}$
MPev	– potencia metabólica media de las acciones ≥20 $W \cdot kg^{-1}$
MSRD	– distancia recorrida a media velocidad (14-18 $km \cdot h^{-1}$), en metros
MW	– trabajo metabólico, en kJ
Pmax	– potencia máxima alcanzada, en $W \cdot kg^{-1}$
PowerE	– número de eventos de alta intensidad o potencia, en $W \cdot kg^{-1}$
RPE	– percepción subjetiva del esfuerzo
SPD	– distancia recorrida a sprint (>24 $km \cdot h^{-1}$), en metros
SSG	– juegos en espacios reducidos
TD	– día de entrenamiento
TL	– carga de entrenamiento
TM	– actividad de locomoción
TotalD	– distancia total recorrida, en metros
UA	– unidades arbitrarias
VHSRD	– distancia recorrida a muy alta velocidad (21-24 $km \cdot h^{-1}$), en metros
Vmax	– velocidad máxima alcanzada, en $km \cdot h^{-1}$
WalkD	– distancia recorrida andando (0-7 $km \cdot h^{-1}$), en metros

II. Abbreviations

Abbreviations

GPS	– global positioning system
HIRD	– total high-intensity distance for all speed > 14 $km \cdot h^{-1}$, in meters
HSRD	– high-speed running distance (18-21 $km \cdot h^{-1}$), in meters
ML	– match load
SPD	– sprint running distance (> 24 $km \cdot h^{-1}$), in meters
TL	– training load
TM	– time motion
TotalD	– total distance, in meters

III. Resumen

Resumen

El fútbol es un deporte complejo caracterizado por una interacción continua entre multitud de factores que requiere la adaptación constante de los jugadores ante diferentes situaciones o estímulos que surgen espontáneamente. Durante el juego, los jugadores tienen que ejecutar diferentes acciones técnico-tácticas a la vez que realizan distintos tipos de esfuerzos físicos de gran intensidad, y en estas situaciones deben ser capaces de tomar decisiones muy rápidas y reactivas ante estímulos inesperados. Por ejemplo, un futbolista que está corriendo a máxima velocidad en conducción de balón por la banda con la presión de un jugador contrario que intenta continuamente robarle el balón, con la intención de buscar un centro a área hacia un compañero que se desmarca y busca rematar a portería. Por tanto, los jugadores precisan una condición física óptima para aguantar las grandes exigencias de la competición y poder llevar a cabo estas acciones con mayor éxito. Realizar una correcta monitorización y planificación de la carga de los jugadores es de vital importancia en el fútbol, más aún a nivel profesional donde los jugadores acumulan un gran número de partidos a lo largo de la temporada. La monitorización de la carga mediante los sistemas de posicionamiento global (GPS) se ha mostrado como un método adecuado y fiable para cuantificar las diferentes actividades de locomoción (TM, *time motion*) tanto en entrenamiento como en partido, y es ampliamente utilizado por los equipos profesionales (Buchheit et al., 2014; Hoppe, Baumgart, Polglaze, & Freiwald, 2018; Pons et al., 2019). Además, el contexto en el que tenga lugar la competición debe ser considerado en la monitorización y planificación de la carga con la finalidad de conseguir un mejor nivel de preparación de los jugadores para un escenario específico. En este sentido, el periodo de la temporada, la calidad del equipo al que enfrentarse o la localización del encuentro, entre otros, son factores que afectan a las respuestas físicas de los jugadores.

El objetivo principal de esta Tesis Doctoral consiste en realizar un análisis exhaustivo de las actividades de TM realizadas por futbolistas profesionales a lo largo de una temporada en función de la posición de juego y considerando diferentes factores contextuales dentro de la monitorización y programación de la cara con el fin de mejorar el nivel de preparación de los jugadores ante escenarios contextuales específicos.

La muestra objeto de estudio en esta investigación se corresponde a la carga externa (i.e., actividades de TM) realizada por futbolistas pertenecientes a tres equipos profesionales compitiendo en las tres máximas categorías españolas de Primera, Segunda y Segunda división B, en entrenamiento y competición a lo largo de una temporada, monitorizado mediante tecnología GPS.

El primer estudio de esta investigación analiza las respuestas físicas realizadas en entrenamiento por futbolistas de élite considerando los factores contextuales que definen el escenario específico de la competición. De esta manera, se establecen modelos o ecuaciones de predicción de diferentes parámetros de TM considerando el efecto de la calidad del oponente, periodo de temporada y localización del encuentro sobre la carga de entrenamiento (TL, *training load*) mostrada por los jugadores. Competir en alto nivel es muy exigente y cualquier factor que ayude a mejorar el sistema de cuantificación y monitorización de la carga puede ser de gran utilidad para entrenadores y preparadores físicos para optimizar el proceso de entrenamiento. Por tanto, este estudio propone un nuevo e innovador enfoque para la cuantificación de la TL que podría ser de gran utilidad en la práctica con objeto de conseguir una mejor preparación de los jugadores para el escenario específico del partido próximo.

El segundo estudio de esta Tesis analiza y compara las respuestas físicas mostradas por los jugadores tanto en entrenamiento como en competición durante las cuatro semanas previas y posteriores a la destitución del entrenador en tres equipos españoles compitiendo en Primera, Segunda y Segunda división B. En el fútbol de alto nivel lo más importante es ganar. Destituir al entrenador a mitad de temporada tras una racha de resultados negativos es una práctica común entre los clubes profesionales en el intento de revertir la situación. Tener conocimientos sobre cómo puede ser el comportamiento físico de los futbolistas tras la destitución de un entrenador puede ser útil para los clubes a la hora de determinar si el cambio de entrenador podría suponer un estímulo positivo para los jugadores.

A día de hoy no se sabe de forma precisa cuál es la TL más apropiada que deben realizar los jugadores a lo largo del microciclo para optimizar el rendimiento en competición. En el tercer estudio se examina si la carga que realizan los jugadores durante la semana de entrenamiento puede predecir el rendimiento físico que posteriormente muestren los jugadores en el partido siguiente. Esta información puede ser realmente útil para los entrenadores y preparadores físicos en la práctica ya que permite conocer mejor el nivel de preparación de los jugadores para hacer frente a las demandas de la competición.

Por último, se ha realizado un artículo en formato de carta editorial (estudio 4) en el que se ha reunido la opinión de expertos profesionales del fútbol de nivel internacional sobre la repercusión y los posibles efectos a corto y largo plazo en el rendimiento físico y la incidencia de lesiones de futbolistas profesionales del cese total de la actividad por confinamiento (cuarentena) como consecuencia de la pandemia mundial del coronavirus una vez los equipos retomen la actividad y vuelvan a los entrenamientos y competición. Desde un enfoque práctico, este artículo ofrece una recopilación y relación de conocimientos para entender cómo el periodo de cuarentena puede afectar al rendimiento físico de los jugadores en el fútbol de alto nivel, basándose en la amplia trayectoria y experiencia de profesionales dentro del área de acondicionamiento de equipos de fútbol de alto nivel de todo el mundo, junto con el conocimiento aportado por la ciencia.

De forma generalizada, la presente Tesis Doctoral evidencia la existencia de una alta variabilidad en el rendimiento físico mostrado por futbolistas profesionales en función de la posición de juego y considerando diferentes factores contextuales. Por tanto, se demuestra la importancia de contextualizar la carga a un escenario específico con objeto de mejorar la periodización de la carga durante la semana de entrenamiento para optimizar el rendimiento físico de los jugadores en el siguiente partido.

Desde un enfoque más específico, los principales hallazgos de esta Tesis se pueden resumir en los siguientes puntos:

I. Existe variabilidad en las respuestas físicas mostradas por los jugadores tanto en entrenamiento como en competición considerando diversos factores contextuales como el periodo de la temporada, la localización del encuentro (en casa o fuera) o la calidad del equipo rival, entre otros.

II. Los futbolistas muestran un comportamiento físico diferente tras la destitución del entrenador a mediados de temporada.

III. La carga que realizan los futbolistas durante la semana de entrenamiento puede predecir el rendimiento físico que posteriormente mostrarán en el siguiente partido.

IV. Todos los expertos coincidieron en que los futbolistas mostrarían menor capacidad física en la vuelta a la actividad tras el periodo de cuarentena por coronavirus. Realizar una periodización y programación de la carga óptima cuando retome la competición es muy importante para no incurrir en un aumento de la incidencia de lesiones.

Palabras clave: fútbol; rendimiento; monitorización; actividades de locomoción; factores contextuales.

IV. Abstract

Abstract

'Monitoring and quantification of training- and match- load in top elite soccer players and practical applications on tasks design'

Soccer is a complex sport characterized by the continuous interaction between a myriad of factors that require the constant adaptation and quick reaction of the players with different incoming situations or stimulus. During the game, players have to perform different technical-tactical skills while making diverse high-intensity efforts, and must be able to make quick and reactive decisions with unexpected stimulus. For instance, when the player is running at maximum speed on the wing with ball possession under pressure from an opposing player who is constantly trying to steal him the ball, with the objective of looking for a cross into the box to a teammate to shoot at goal. Accordingly, players need an optimal conditioning to withstand the high demands of competition and develop these actions successfully. Developing an appropriate monitoring and planification of players' workload is paramount in soccer, specially at professional level where players accumulate a large number of matches across the season. Global positioning systems (GPS) are valid and reliable tools to quantify the time motion (TM) activity both in training and matches, and are widely used by professional teams (Buchheit et al., 2014; Hoppe et al., 2018; Pons et al., 2019). In addition, the context of the competition should be considered in the monitoring and programming of the load in order to improve the readiness of players for a specific scenario. Accordingly, the factors season period, the quality of opponent or the match location, among others, affect the physical responses of the players.

The main objective of this Doctoral Thesis consists on performing an exhaustive analysis of the TM activity developed by professional players throughout the season, according to the playing position and considering several contextual factors within the load monitoring and programming in order to improve the readiness of players to specific contextual-scenarios.

The sample of this investigation is based in the external load (i.e., TM variables) performed by players belonging to three professional teams competing in the top three standards of Spanish soccer: First, Second and Second B division; both in training and matches over the season and monitored with GPS technology.

The first study of this investigation analyses the physical responses performed in training by elite players considering the contextual factors of the specific match-scenario. Prediction models of different TM parameters are established considering the effect of the opponent quality, season period and match location on the training load (TL) showed by players. High-level competition is very demanding and any improve in the monitoring system can be quite helpful for coaches and athletic trainers to optimize the training process. Therefore, this study proposes a new and innovative approach for TL quantification that might be very useful in practice in order to improve the specific preparation of players for the upcoming match-scenario.

The second study of this Thesis analyses and compare the physical responses of professional soccer players belonging to three Spanish First, Second and Second B division teams both in training and competition during the four weeks before and after a coach turnover. Winning is the most important aspect in high-level soccer. Firing the coach at mid-season after a streak of negative results is a common practice among professional clubs in an attempt to reverse this situation. Gaining knowledge about the physical behaviour of players after the coach dismissal can be useful for Clubs to determine whether the coach turnover could provide a positive stimulus for players.

To this day it is not known what is the most appropriate TL that players should perform throughout the microcycle to optimize the match performance. The third study examines whether the load performed by players during the training week can predict the physical performance that players will afterwards show in following match. This information can be really practical for coaches and athletic trainers as it provides insight into the players' capacity to withstand the match demands.

Finally, the study 4 is an editorial letter gathering the opinions of international soccer experts about the impact and potential effects of short- and long-term coronavirus lockdown (quarantine) on physical performance and injury incidence in high-level soccer players once teams return to training and competition. From a practical approach, this study provides a compilation of knowledge to understand how the quarantine may affect the physical performance of elite soccer players, based on the extensive experience and career path of conditioning area practitioners in professional soccer clubs around the world, together with the knowledge provided by research.

Overall, the present Doctoral Thesis highlights the high variability in the physical performance showed by professional soccer players according to the playing position and taking into account several contextual factors. Thus, the importance of contextualizing the load in relation to a specific match-scenario is shown to improve the load periodization during the training week to optimize the players' physical performance in the upcoming match.

Specifically, the main findings of this Thesis can be summarized in the following points:

I. Players show variability in the physical responses in both training and competition when contextual factors such as season period, match location or opponent quality, among others, are taken into account.
II. Players show different physical behaviour after a mid-season coach turnover.
III. The workload performed by the players during the training week can predict the physical performance they will subsequently show in the following match.
IV. All the experts agreed that soccer players would show a decreased physical performance when they had to return to training after the coronavirus lockdown. Therefore, developing an optimal periodization and programming of workload when the competition returns is paramount to avoid a high injury.

Key words: soccer; performance; monitoring; time motion; contextual factors.

V. Introducción

Introducción

Con alrededor de 270 millones de personas involucradas de forma activa, el fútbol es uno de los deportes más populares e influyentes a nivel mundial (Turner & Stewart, 2014). Debido al gran interés mediático y sociocultural que supone, genera un fuerte impacto económico para la sociedad actual y es a día de hoy es uno de los deportes más practicados mundialmente, haciendo cada vez más complicado y exigente llegar a competir en alto nivel. Además de talento, se requiere una gran dedicación, esfuerzo y sacrificio por parte de los jugadores durante los años que permanezca su carrera deportiva activa. Esta gran popularidad ha conducido a despertar el interés de la comunidad científica, aumentando considerablemente la producción de numerosas líneas de investigación en las últimas décadas.

El fútbol es un deporte de naturaleza compleja donde el aspecto físico, las habilidades técnicas y el componente táctico interactúan conjuntamente en la consecución de rendimiento (Ade, Fitzpatrick, & Bradley, 2016; Baptista, Johansen, Figueiredo, Rebelo, & Pettersen, 2019; Bradley & Ade, 2018; Hughes & Bartlett, 2002; Stølen, Chamari, Castagna, & Wisløff, 2005; Tierney, Young, Clarke, & Duncan, 2016; Yi et al., 2019) (Figura 1). Aunque muchos autores sostienen que los aspectos técnico-tácticos son los más importantes (Castellano, Blanco-Villaseñor, & Álvarez, 2011; Lago-Peñas, 2009), mantener un rendimiento físico óptimo de los jugadores es necesario para que puedan ejecutar dichas acciones técnico-tácticos de forma eficiente (Barnes, Archer, Hogg, Bush, & Bradley, 2014; Bradley et al., 2016). Por tanto, para poder competir en el fútbol profesional, es imprescindible que los jugadores desarrollen y mantengan un nivel elevado en cada uno de estos elementos.

Figura 1. Interacción rendimiento físico, habilidades técnicas y aspectos tácticos para la consecución de rendimiento.

Análisis del rendimiento físico en el fútbol

El fútbol es un deporte de interacción caracterizado por la alternancia de esfuerzos de alta intensidad (Polglaze, Dawson, & Peeling, 2016; Stølen et al., 2005). Diferentes acciones como saltos, aceleraciones, frenadas, carreras a diferentes rangos de velocidad y distancias, giros, luchas con el adversario por la posesión del balón o golpeos de balón, entre otros, son los tipos de esfuerzos que realizan los jugadores durante la práctica. La actividad de locomoción o *Time Motion* (TM) del juego representa la distribución de las diversas formas de desplazamientos y esfuerzos realizados por los jugadores a diferentes umbrales de velocidad o intensidad. Por lo tanto, el análisis del TM es una buena forma de ilustrar el rendimiento físico específico en el fútbol, siendo el método de monitorización más utilizado a nivel profesional (Cardinale & Varley, 2017; Nassis & Gabbett, 2017).

Demandas físicas en el fútbol profesional

La competición de alto nivel muy exigente físicamente y se requiere un elevado nivel condicional de los jugadores para hacer frente a las demandas de la competición a lo largo de la temporada (Bradley et al., 2016; Dellal, Lago-Peñas, Rey, Chamari, & Orhant, 2015; Lago-Peñas, Rey, Lago-Ballesteros, Casáis, & Domínguez, 2011). La monitorización de la carga externa de entrenamiento (TL; *training load*) y de partido (ML; *match load*) es fundamental para diseñar programas de entrenamiento adecuados a fin de obtener una preparación física de los jugadores óptima para la competición y reducir el riesgo de lesión (S. Malone et al., 2017; Owen et al., 2015). Además, resulta muy útil para llevar un control de la evolución la carga en los periodos de recuperación de los jugadores lesionados (Ehrmann, Duncan, Sindhusake, Franzsen, & Greene, 2016; Gabbett, Hulin, Blanch, & Whiteley, 2016; Gabbett et al., 2017; Robertson, Bartlett, & Gastin, 2017). Considerando el hecho que los jugadores entrenan para competir, cuantificar la TL relativo a las demandas de partido ha resultado ser una estrategia muy útil para los entrenadores para optimizar la periodización del entrenamiento (Clemente, Owen, et al., 2019; Clemente, Rabbani, et al., 2019; Dalen, Jørgen, Gertjan, Geir Havard, & Ulrik, 2016; Di Mascio & Bradley, 2013; Kelly, Rabitohs, & Coutts, 2007;

Martín-García, Gómez Díaz, Bradley, Morera, & Casamichana, 2018; Owen, Djaoui, Newton, Malone, & Mendes, 2017; Owen, Lago-Peñas, Gómez, Mendes, & Dellal, 2017). En este contexto, un estudio reciente concluye que la eficiencia de la ML puede predecirse a partir de la carga realizada por los jugadores los días de entrenamiento (TDs, *training days*) previos al partido (Grünbichler, Federolf, & Gatterer, 2019). De forma generalizada, en el transcurso de un partido cada jugador recorre una distancia total media de 10-11 km (Bradley, Lago-Peñas, Rey, & Gomez Diaz, 2013; Mohr, Krustrup, & Bangsbo, 2003), la cual se realiza a diferentes rangos de velocidad, la mayor parte es cubierta a intensidades bajas; andando o a trote suave, en las cuáles predomina el sistema aeróbico (Bangsbo, Mohr, & Krustrup, 2006). Por ejemplo, este tipo de acciones se realiza cuando el equipo está basculando en defensa o si el balón está siendo jugado en una zona del campo muy alejada de la posición del jugador referido. Sin embargo, durante un partido las acciones de mayor determinación se realizan a intensidades máximas o submáximas (Ade et al., 2016; Bradley et al., 2016), como un delantero esprintando en conducción del balón hacia portería contraria, un jugador de banda que busca desmarcarse para recibir un pase en profundidad o un defensor que corre detrás de un oponente para intentar robarle el balón. En equipos profesionales cada jugador realiza entre 150 y 250 acciones de alta intensidad en el partido (Mohr et al., 2003); aceleraciones, frenadas, saltos, etc., con cambios del tipo de actividad cada 4-6 segundos (Andrzejewski, Chmura, Konefał, Kowalczuk, & Chmura, 2018), y realizando acciones de alta intensidad con una frecuencia media de 15-20 segundos (G. Vigne, Gaudino, Rogowski, Alloatti, & Hautier, 2010). Aunque la carrera a sprint sólo representa del 1 al 3 % de la distancia total cubierta por un jugador durante el partido, es una de las actividades de TM más importantes en el fútbol (Andrzejewski, Chmura, Pluta, Strzelczyk, & Kasprzak, 2013; Andrzejewski et al., 2018; Dellal et al., 2011). Mohr (2003) encontró que los jugadores realizaron sprints de 2 a 4 segundos cada 90-180 segundos de media. Por lo tanto, el análisis de las acciones realizadas a diferentes intensidades es una buena forma de ilustrar el rendimiento físico (número de sprints, distancia recorrida a alta intensidad, frecuencia con la que se realizan acciones a máxima velocidad, etc.) (Carling, 2013; Di Salvo, Gregson, Atkinson, Tordoff, & Drust, 2009; Mohr et al., 2003). En una revisión con meta-análisis reciente se ha concluido que la distancia de carrera cubierta por encima de 5.5 $m \cdot s^{-1}$ (i.e., actividad de intensidad muy alta) representa el parámetro de monitorización que mejor refleja los cambios en las respuestas biomecánicas y neuromusculares post-partido (Hader et al., 2019). Por cada 100 m recorridos por encima de esta velocidad durante el partido, la concentración de cretina-quinasa (parámetro fisiológico indicador de daño muscular) puede aumentar hasta un 30% durante las 24 horas post-partido. Por tanto, una programación de la carga inadecuada podría incurrir en un aumento considerable del riesgo de lesión (S. Malone et al., 2017; Owen et al., 2015), quedando en manifiesto la necesidad de realizar un control y monitorización de la carga de los jugadores adecuado.

Existen diferencias significativas en el rendimiento físico realizado por los jugadores a lo largo del partido, encontrándose mayores respuestas en la primera parte respecto a la segunda (Abade et al., 2017; Bangsbo et al., 2006; Lago-Peñas, 2012; Mohr et al., 2003; Mohr, Krustrup, & Bangsbo, 2005; G. Vigne et al., 2010). Algunas de las diferencias más significativas en el rendimiento físico de la segunda parte respecto a la primera son:

i. Disminución de la distancia total y la distancia a alta intensidad (Mohr et al., 2003; G. Vigne et al., 2010).
ii. Aumento del número de periodos de recuperación de más de 120 segundos (G. Vigne et al., 2010).
iii. Aumento de la distancia recorrida andando (Bradley et al., 2009).
iv. Incremento significativo del nivel de fatiga de los jugadores en los últimos 15 minutos de la segunda parte (Mohr et al., 2003; G. Vigne et al., 2010; Gregory Vigne et al., 2013).

La reducción del rendimiento físico en la segunda parte, principalmente en la actividad de alta intensidad, es debido a la fatiga que acumulan los jugadores a lo largo del partido (Bangsbo et al., 2006; Mohr et al., 2003, 2005). Estos efectos son mucho más notables cuando los parámetros son expresados en términos relativos (i.e., distancia por minuto) (G. Vigne et al., 2010). De hecho, existen estudios que sólo muestran diferencias en las repuestas físicas entre la primera y la segunda parte cuando se consideran los valores en términos relativos y no en absolutos. En este contexto, es importante para los entrenadores tener conocimiento sobre la trascendencia de realizar las sustituciones oportunas durante el partido ya que pueden resultar decisivas para mantener o aumentar el rendimiento físico del equipo cuando la fatiga empiece a verse reflejada en los jugadores a lo largo de la segunda parte (Bradley, Lago-Peñas, & Rey, 2014; Giménez, Leicht, & Gomez, 2019; Lago-Peñas, 2012). En este sentido, Bradley et al. (2014) encontraron que los jugadores que entraron en la segunda parte como suplentes cubrieron de un 10 a 27% más distancia de alta intensidad que los jugadores que llevaban jugando todo el partido, y además recorrieron un 15% más distancia comparado con el mismo periodo de tiempo cuando jugaron el partido completo (Lago-Peñas, 2012). Además, estos autores también encontraron valores menores en las respuestas físicas de los jugadores en los primeros minutos de la segunda parte en comparación al resto del partido principalmente causado por la bajada de temperatura corporal de los jugadores durante el descanso.

Cuando se analiza cada periodo por separado, también se produce un menor rendimiento físico de los jugadores en los últimos minutos de cada parte. Por ejemplo, la distancia a sprint se reduce significativamente al final de ambos periodos (Andrzejewski et al., 2018; Bradley et al., 2009). Además, tras los periodos más intensos del partido, en los que existe un aumento de las acciones de alta intensidad hasta del 125% (Di Mascio & Bradley, 2013), se produce una disminución del rendimiento de los jugadores durante los minutos posteriores (Lago-Peñas, 2012; Sparks, Coetzee, & Gabbett, 2016). Lago-Peñas (2012) encontró una reducción del 8% de la carrera de alta intensidad respecto a la media tras el periodo más intenso del partido; mientras que Sparks et al. (2016) concluyen que la actividad de alta intensidad está fuertemente afectada tras el periodo de 5 minutos más intenso de cada parte. No obstante, es importante considerar que la disminución del rendimiento físico también puede ser causado por factores tácticos, técnicos o psicológicos (Alexandre et al., 2012).

Monitorización de la carga

Actualmente, los medios o herramientas de monitorización de la actividad de TM de los jugadores más comunes en el fútbol son los sistemas de seguimiento de vídeo semiautomático (*video-tracking*), y los sistemas de posicionamiento global (GPS) (Buchheit et al., 2014; Hoppe et al., 2018; Pons et al., 2019). Ambos son métodos válidos y fiables para la monitorización de las actividades de locomoción de los jugadores. El video-tracking consiste en un sofisticado sistema semiautomático de múltiples cámaras situadas alrededor del campo basado en la captación del movimiento de los jugadores durante el partido, computarización y procesamiento de datos que permite proporcionar información del rendimiento físico y técnico-táctico de los jugadores a tiempo real (Buchheit et al., 2014). Este medio de monitorización presenta el inconveniente de que es un sistema de medición fijo, y por tanto no puede ser fácilmente transportado para utilizar en diferentes campos de juego. Por el contrario, los sistemas GPS son unos pequeños dispositivos que se colocan en la espalda de los jugadores, entre las escápulas, fijados dentro de unas camisetas o chalecos ajustados que no restringen el movimiento de los jugadores (Hoppe et al., 2018; Theodoropoulos, Bettle, & Kosy, 2020), y por tanto pueden ser fácilmente transportados y utilizados en cualquier lugar que sea un espacio abierto, ya que la tecnología GPS se basa en la detección del movimiento de los jugadores mediante una emisión continua de la posición de los jugadores a 27 satélites situados en órbita (Theodoropoulos et al., 2020). De esta manera, los dispositivos de GPS miden la posición, velocidad y aceleración, para posteriormente procesar los datos mediante diversos algoritmos y filtros y proporcionar así un conjunto de variables que pueden utilizarse para cuantificar la carga externa de los jugadores. Actualmente casi todos los dispositivos GPS utilizados en el deporte incorporan un acelerómetro triaxial que proporciona además una medida de la aceleración que puede utilizarse para estimar la carga externa total a la que es sometida el cuerpo. Además, estos dispositivos también pueden disponer de un magnetómetro y/o un giróscopo en su interior, los cuales, permiten medir la dirección, orientación, y angulación del movimiento, respectivamente (Cardinale & Varley, 2017). Aunque su fiabilidad y validez ha sido ampliamente demostrada (Hoppe et al., 2018; J. Malone, Lovell, Varley, & Coutts, 2017; Terziotti, Sim, & Polglaze, 2018), un aspecto importante a considerar es que actualmente existe un posible error entre unidades, lo que hace necesario que los jugadores lleven siempre el mismo dispositivo a fin de evitar errores en la medición (J. Malone et al., 2015, 2017; Owen, Djaoui, et al., 2017). De cualquier manera, la tecnología GPS es la herramienta de monitorización para el control de la carga de entrenamiento y competición más fiable y utilizada en el fútbol profesional (Buchheit et al., 2014; Cardinale & Varley, 2017; Ehrmann et al., 2016; J. Malone et al., 2017; Owen, Djaoui, et al., 2017).

A día de hoy, todavía no se han establecido unos umbrales o rangos de intensidad y/o velocidad comunes para agrupar los diferentes parámetros de TM. Según el estudio, país, herramienta de monitorización o marca se utilizan unos rangos concretos. Tras una extensa revisión, Barnes et al. (2014) establece unos umbrales de velocidad que han mostrado ser válidos y que han sido ampliamente utilizados en la literatura por otros autores (Bradley et al., 2009, 2016; Di Salvo et al., 2009; Mohr et al., 2003; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009) (Tabla 1). Según el parámetro considerado, se mide la distancia recorrida o el número de acciones, pudiendo ser representado en términos absolutos (i.e., metros o eventos totales) o relativos (i.e., metros o eventos por minuto). Barnes et al. (2014) definieron como actividad de alta intensidad todas aquellas acciones realizadas a velocidad superior 19.8 $km \cdot h^{-1}$, incluyendo también las aceleraciones, desaceleraciones e impactos. Sin embargo, no existe consenso en la literatura debido a que hay otros autores que concluyen que la actividad de alta intensidad debe ser considerada a partir de 15 $km \cdot h^{-1}$ (Bangsbo, Nørregaard, & Thorsø, 1991). Abt & Lovell (2009) recomiendan individualizar los umbrales de alta intensidad ya que según la capacidad aeróbica de los jugadores presentarán un umbral ventilatorio 2[1] distinto. No obstante, en caso de no poder individualizarse por el motivo que fuere, estos autores apoyan la propuesta inicial de Bangsbo et al. (1991) en la que la actividad de alta intensidad debe ser definida a partir de 15 $km \cdot h^{-1}$, ya que se asemeja a la velocidad media del umbral ventilatorio 2 que alcanzaron los jugadores en su estudio (Abt & Lovell, 2009).

Tabla 1. Actividades de locomoción más comunes en el fútbol. (Extraído de Barnes et al., 2014 & Ehrmann et al., 2016).

Variable	**Rango de velocidad**	**Unidades valoradas**
Parado	0-0.6 $km \cdot h^{-1}$	Distancia (metros)
Andando	0.7-7.1 $km \cdot h^{-1}$	Distancia (metros)
Carrera a velocidad baja	7.2-14.3 $km \cdot h^{-1}$	Distancia (metros)
Carrera velocidad media	14.4-19.7 $km \cdot h^{-1}$	Distancia (metros)
Carrera a velocidad alta	19.8-25.1 $km \cdot h^{-1}$	m / número acciones
Carrera a sprint	> 25.1 $km \cdot h^{-1}$	m / número acciones
Aceleraciones	> 3 $m \cdot s^{-2}$ (en ≤ 0.5 seg)	m / número acciones
Desaceleraciones	> 3 $m \cdot s^{-2}$ (en ≤ 0.5 seg)	m / número acciones
Impactos	> 2 G (en ≤ 0.1 seg)	Número acciones

[1] El umbral ventilatorio 2, también llamado umbral anaeróbico, se corresponde con el punto de transición entre el sistema aeróbico con sistema anaeróbico.

En las últimas décadas, la mayoría de investigadores y preparadores físicos han utilizado parámetros de TM basados en la velocidad de carrera o intensidad, como las distancias cubiertas a diferentes rangos de velocidad o el número de aceleraciones y frenadas, entre otros (Ehrmann et al., 2016; J. Malone et al., 2017; Owen, Lago-Peñas, et al., 2017). Sin embargo, existen autores que sostienen que el enfoque tradicional basado en la velocidad de carrera no representa las demandas físicas reales del fútbol ya que no considera el coste energético asociado a las fases de aceleración en la carrera de alta intensidad (Gaudino et al., 2014, 2013), cuando las aceleraciones producen mayores demandas energéticas que la carrera a velocidad constante, independientemente del rango de velocidad (Cardinale & Varley, 2017). En este sentido, el enfoque metabólico es considerado un método reciente óptimo para obtener el coste energético derivado de las actividades de locomoción (p.ej., aceleraciones, desaceleraciones o distancia de alta intensidad) por unidad de tiempo (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010; Polglaze & Hoppe, 2019). Variables como la potencia metabólica media, la máxima potencia o el número de acciones de alta potencia, entre otras, representan la capacidad aeróbica de los deportistas (Polglaze & Hoppe, 2019), permitiendo una estimación precisa del coste energético y las demandas metabólicas de la actividad cuando se consideran diferentes parámetros de locomoción de forma conjunta (Osgnach & Di Prampero, 2018). Este innovador enfoque ha mostrado ser válido para representar la actividad de alta intensidad que caracteriza el fútbol ya que muestra una relación positiva con el enfoque tradicional basado en la velocidad de carrera (Castagna, Varley, Póvoas, & D'Ottavio, 2017).

Diferencias entre posiciones de juego

Ha sido ampliamente demostrado las diferentes respuestas físicas demandadas por los jugadores según su demarcación en el campo (Castillo-Rodríguez, Cano-Cáceres, Figueiredo, & Fernández-García, 2020; Di Salvo et al., 2009; J. Malone et al., 2015; Martín-García et al., 2018; Martín-López, Mendes, & Castillo-Rodríguez, 2018; Owen, Djaoui, et al., 2017; Owen et al., 2016; Owen, Lago-Peñas, et al., 2017). Aunque se han utilizado diferentes clasificaciones, la literatura comúnmente distingue entre 5 posiciones de juego; defensa central (CD), defensa lateral (ED), centrocampista (CM), interior (WM) y delantero (FO) (J. Malone et al., 2015; Martín-López et al., 2018;

Owen, Djaoui, et al., 2017; Owen et al., 2016; Owen, Lago-Peñas, et al., 2017). Debido al rol específico que desempeñan en el partido, cada una de estas posiciones demandan unas respuestas físicas distintas, además de diferente relación entre trabajo y descanso (Suarez-Arrones et al., 2015). No obstante, es importante tener en cuenta que existen factores contextuales como el estilo de juego del equipo o la calidad del equipo rival, entre otros, de los que se hablará más adelante, que pueden afectar sobremanera al rendimiento físico de los jugadores durante el partido. Por tanto, hay que tener precaución a la hora de interpretar y comparar los resultados de rendimiento físico de futbolistas con los valores utilizados en los diferentes estudios. De forma generaliza, las diferencias más significativas entre posiciones son:

i. Los *centrocampistas* y *los jugadores de banda* son los que recorren mayor distancia a alta intensidad (Abt & Lovell, 2009; Al Haddad, Simpson, Buchheit, Di Salvo, & Mendez-Villanueva, 2015; Di Salvo et al., 2009; Lago-Peñas et al., 2011; Mohr et al., 2003; Rampinini, Coutts, et al., 2007; Rampinini et al., 2009).
ii. Los *delanteros* realizan un mayor número de sprints de corto recorrido y realizados de forma explosiva (Di Salvo et al., 2009; Mohr et al., 2003).
iii. Los *centrocampistas* recorren distancia total superior y realizan esfuerzos de alta intensidad con mayor frecuencia (Abt & Lovell, 2009; Al Haddad et al., 2015; Di Salvo et al., 2009; Lago-Peñas et al., 2011; Mohr et al., 2003; Rampinini, Coutts, et al., 2007; Rampinini et al., 2009).
iv. Los *defensas centrales* son los jugadores que realizan menos distancia a alta intensidad, y la mayoría de las acciones son sin balón (Abt & Lovell, 2009; Al Haddad et al., 2015; Di Salvo et al., 2009; Lago-Peñas et al., 2011; Mohr et al., 2003; Rampinini, Coutts, et al., 2007; Rampinini et al., 2009). Además, son los que realizan mayor distancia corriendo de espaldas (Mohr et al., 2003).
v. Los *jugadores de banda ofensivos (interiores o extremos)* realizan un mayor número de acciones a máxima velocidad, con acciones de mayor distancia y duración (Abt & Lovell, 2009; Al Haddad et al., 2015; Di Salvo et al., 2009; Lago-Peñas et al., 2011; Mohr et al., 2003; Rampinini, Coutts, et al., 2007; Rampinini et al., 2009), y alcanzan un porcentaje mayor de su velocidad máxima individual (Al Haddad et al., 2015).

Monitorizar y programar la TL considerando las demandas específicas por posición es imprescindible en alto nivel. Con el método tradicional de monitorización se cuantifica las diferentes actividades de alta intensidad, pero no se considera que tipo de acción técnica o táctica se está realizando durante la carrera (Bradley & Ade, 2018). Estos autores han desarrollado un nuevo sistema de monitorización mediante un modelo integrado que cuantifique de forma específica la actividad de alta intensidad contextualizada a las acciones técnicas y tácticas claves que se producen en un partido según la posición de juego. El rol táctico que desempeña un jugador es un importante determinante del rendimiento físico del partido, y considerar un único enfoque para todo el equipo puede resultar confuso y muy difícil de interpretar debido la disparidad de acciones y movimientos entre posiciones (Bradley & Ade, 2018). Como se puede apreciar en la Figura 2, aunque dos posiciones muestren una distancia de alta intensidad similar, la forma en la que realizan esa actividad puede ser muy diferente. Por ejemplo, estos autores observaron en su estudio que los EDs normalmente realizan giros de 90 a 180º antes de iniciar una carrera en la transición ataque-defensa; las acciones con balones a la espalda suponían el 20% de la distancia total recorrida a alta intensidad de un CD, por lo que la carrera iba precedida además de un giro de 0 a 90º previo, etc. No obstante, Bradley & Ade (2018) sostienen la necesidad de individualizar la TL debido a las diferencias existentes entre jugadores dentro de una misma posición según el estilo de juego particular de cada uno. En esta línea, cada vez hay un mayor número de autores que concluyen que la interpretación del análisis de las diferentes acciones a alta velocidad debe ser individual, ya que existe una gran variabilidad entre partidos, dentro del propio partido y entre jugadores, incluso jugando en la misma posición (Bradley & Ade, 2018; Carling, Bradley, McCall, & Dupont, 2016; Gregson, Drust, Atkinson, & Salvo, 2010).

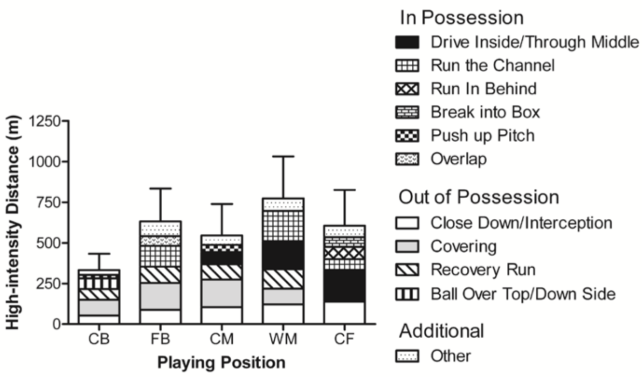

Figura 2. Distancia de alta intensidad contextualizada recorrida en partido por posición; (CB, defensa central; FB, defensas laterales; CM, centrocampista; WM, interior; CF, delantero centro. Nota: la parte inferior de cada columna es referida a las variables sin posesión, mientras que la parte superior incluye las variables con posesión para cada posición (Extraído de Bradley & Ade, 2018).

Periodización de la carga

Es imperativo desarrollar y programar la TL de los jugadores con el fin de que puedan hacer frente a las demandas de la competición, más aún en alto nivel donde acumulan un gran número de partidos a lo largo de la temporada (Ehrmann et al., 2016; Gabbett, 2016). En un deporte colectivo como el fútbol, donde normalmente hay un partido semanal, o incluso dos o tres partidos durante ciertos periodos de la temporada si se trata de la élite, los jugadores necesitan mantener una capacidad física óptima continuamente a lo largo de la temporada que les permita acometer las exigencias de la competición y no incurrir en mayor riesgo de lesión (Seirul-lo et al., 2017). Exceptuando pretemporada y los periodos transitorios (p.ej., verano o Navidad), la periodización de la carga normalmente se estructura en microciclos semanales basados en el día de partido (MD, *match day*), el cuál coincide normalmente en fin de semana (J. Malone et al., 2015; Owen, Lago-Peñas, et al., 2017). Por tanto, la clasificación de los TDs de un microciclo semanal quedaría de la siguiente manera: MD-4, MD-3, MD-2 y MD-1, referido al TD realizado 4, 3, 2 y 1 día antes del MD, respectivamente. La literatura también hace referencia a los días correspondientes a MD-5, 5 días antes del partido; y/o MD+1 o MD+2, referidos a las sesiones 1 y 2 días después del partido, respectivamente (Oliveira et al., 2019; Stevens, de Ruiter, Twisk, Savelsbergh, & Beek, 2017). Sin embargo, los registros anteriores a MD-4 (i.e., MD-5, MD+1 y MD+2) durante el periodo competitivo habitualmente se corresponden a sesiones de recuperación post-partido y no presentan contenidos específicos de carga (Owen et al., 2016; Owen, Lago-Peñas, et al., 2017). Existen diferencias significativas en el volumen e intensidad de la carga entre los TDs del microciclo (Clemente, Owen, et al., 2019; Lago-Peñas et al., 2011; Martín-García et al., 2018; Mohr et al., 2003). Considerando un microciclo con un partido semanal, todos los estudios coinciden en que los TDs con mayor carga absoluta se realizan a mediados del microciclo, MD-4 y MD-3; y a partir de ahí se reduce progresivamente la carga hasta el MD-1 con objeto de conseguir un mejor estado de forma el MD. Como se ha comentado anteriormente, el fútbol es un deporte caracterizado por la alternancia de esfuerzos de alta intensidad o velocidad (Ade et al., 2016; Bradley et al., 2016). A fin de obtener una preparación óptima para el partido, Grünbichler et al. (2019) concluyeron que los entrenadores deberían programar sesiones de entrenamiento de sprint 3-4 días antes y evitar cargas elevadas y sesiones de larga duración el día previo al partido. En la Tabla 2 se muestra un ejemplo de un microciclo con un partido semanal correspondiente al periodo competitivo de un equipo de élite europeo. Como se puede apreciar, según el día del microciclo se trabajan cualidades condicionales diferentes. Además, Martín-García et al. (2018) argumentan la necesidad de contextualizar cada TD a diferentes objetivos. En su estudio, el MD-4 estaba orientado al entrenamiento de la fuerza y la potencia por medio de tareas de posesión y juegos en espacios reducidos (SSGs); MD-3 era para preparar la táctica que emplearían en el siguiente partido mediante tareas de intensidad media y alta, y juegos posicionales (p.ej., 11 vs 11); en el MD-2 se entrenaban los elementos técnicos individuales de los jugadores y la táctica por medio de tareas específicas por posición; y el MD-1 se orientaba a ejercicios de activación a intensidad baja y acciones a balón parado.

Tabla 2. Microciclo de entrenamiento con un partido semanal (Extraído de Owen, Lago-Peñas et al., 2017).

	MD-5	**MD-4**	**MD-3**	**MD-2**	**MD-1**	**MD**	**MD+1**
Mañana	Descanso	ACTIV WU/VC F-T WU/VC	ACTIV WU/VC F-T WU/VC	ACTIV WU/VC T-T WU/VC	ACTIV WU/VC T-T WU/VC	Descanso	Descanso
Tarde	Descanso	Gym	Gym	Descanso	Descanso	Partido	Descanso

MD: Match day, día de partido; ACTIV: Activación; WU/VC: Calentamiento/Vuelta a la calma; F-T: físico-táctico; T-T; técnico-táctico; Gym: entrenamiento en gimnasio.

Como se ha comentado anteriormente, en el fútbol profesional es frecuente que los equipos dispongan de un calendario de competición muy congestionado durante gran parte de la temporada, con partido cada 3 días (Carling, Le Gall, & Dupont, 2012;

Dellal et al., 2015; Djaoui et al., 2014; Lago-Peñas et al., 2011; Oliveira et al., 2019). Ninguno de los autores encontró diferencias en el rendimiento físico de los futbolistas (p.ej., distancia total o distancia en los diferentes rangos de velocidad) en partido al comparar los microciclos de uno y dos partidos semanales. La literatura muestra que un periodo de recuperación entre partidos de 72 a 96 horas es suficiente para mantener una capacidad física adecuada, pero no para mantener un índice de lesiones bajo (Dupont et al., 2010). Durante un cierto periodo de tiempo los jugadores pueden hacer frente a un calendario congestionado, compitiendo cada 3 días, sin bajar el rendimiento, aunque podrían acumular cierta fatiga residual que los exponga a un mayor riesgo de lesión (Dellal et al., 2015; Lago-Peñas et al., 2011). Dellal et al. (2015) encontraron que la incidencia total de lesiones (considerando las sesiones de entrenamiento y los partidos de forma conjunta) durante un periodo congestionado (i.e., 2 partidos a la semana) fue similar a un periodo no congestionado (i.e., 1 partido semanal); mientras que aumentó significativamente considerando sólo los partidos. Por el contrario, Carling et al. (2012) no encontraron un aumento de la incidencia de lesiones en partido respecto a entrenamiento. A pesar de que los jugadores titulares muestran mayor carga interna y externa que los suplentes durante los periodos congestionados cuando se consideran conjuntamente la carga de entrenamiento y competición (Gualtieri, Rampinini, Sassi, & Beato, 2020), jugar dos partidos en una semana no parece ser una carga excesiva para los jugadores que implique la necesidad de realizar rotaciones en la alineación (Lago-Peñas et al., 2011). Finalmente, aunque existen autores que han encontraron que un calendario congestionado durante un periodo prolongado no afectaba al rendimiento físico de futbolistas de élite en competición (Djaoui et al., 2014), se debería determinar durante cuánto tiempo los jugadores pueden mantener el rendimiento elevado jugando dos partidos semanales. De cualquier manera, el hecho de incluir más de un partido semanal en el microciclo implica un diseño y periodización de la TL completamente diferente. En este tipo de microciclo, el objetivo principal de las sesiones de entrenamiento desarrolladas en los días entre partidos debe ser la de favorecer los procesos de recuperación de los jugadores en el intento de proteger a los jugadores ante factores potenciales de riesgo de lesión (Dellal et al., 2015; Oliveira et al., 2019).

La carga realizada por los jugadores durante las semanas anteriores (i.e., carga acumulada o crónica) es otro aspecto muy importante a tener en cuenta en la programación de la TL a fin de prevenir lesiones (Blanch & Gabbett, 2015; Bowen, Gross, Gimpel, & Li, 2017; Gabbett, 2016; Gabbett et al., 2016; Hulin, Gabbett, Lawson, Caputi, & Sampson, 2016; S. Malone et al., 2017). De acuerdo con la literatura, los preparadores físicos deberían cuantificar y llevar un control de la carga semanal, la diferencia de carga de una semana a otra, la carga acumulada durante las 2, 3 y 4 semanas previas, y la relación entre la carga aguda (i.e., carga correspondiente a la semana o microciclo actual) y la carga crónica (i.e., carga acumulada de las semanas anteriores), conocido como '*Acute:chronic workload ratio*' (A:C WL ratio). El A:C WL ratio indica el estado de preparación física del jugador y además es considerado un importante predictor de riesgo de lesiones en el fútbol (Gabbett et al., 2016). Una elevada carga crónica junto con una carga aguda reducida mejora el rendimiento físico de los jugadores, mientras que una carga crónica sumado a una carga aguda elevada expone a los jugadores a un alto riesgo de lesión. En este contexto, S. Malone et al. (2017) establece un A:C WL ratio entre 1 y 1.25 UA (unidades arbitrarias) como rango de protección de lesiones en el fútbol, considerando como carga crónica un periodo de 4 semanas. Cargas por encima o por debajo de este rango implica un mayor riesgo de lesión. Tanto éste como la mayoría de estudios utilizan la escala percepción subjetiva del esfuerzo (RPE) CR10 de Börg como herramienta de valoración de la carga interna en el A:C WL ratio. Estableciendo la RPE como carga, las conclusiones principales pueden resumirse en:

i. Grandes picos de carga aguda en relación con la carga crónica aumentan 70 veces el riesgo de lesión (Blanch & Gabbett, 2015; Gabbett, 2016; Gabbett et al., 2016).
ii. Rápidos o largos picos de carga RPE aumentan el riesgo de lesión (Gabbett, 2016; Gabbett et al., 2016; S. Malone et al., 2017).
iii. Aumentos semanales de la carga RPE superiores al 10% de la carga crónica se asocia a un mayor riesgo de lesión (Blanch & Gabbett, 2015; Gabbett, 2016; Gabbett et al., 2016). De la misma manera, aumentos semanales de 350 a 550 UA aumenta el riesgo de lesión (S. Malone et al., 2017).
iv. A:C WL ratio de protección de lesiones en el fútbol: 1-1.25 UA (S. Malone et al., 2017).

Otros autores han considerado las variables de TM como parámetros de carga externa, encontrando resultados similares: cargas agudas muy elevadas, recorrer una distancia total de más de 28798 metros durante la semana (Hulin et al., 2016), o realizar más de 9254 aceleraciones durante un periodo de 3 semanas se han mostrado como importantes indicadores de riesgo de lesión (Bowen et al., 2017). Hulin et al. (2016) argumentaron que el mayor riesgo de lesión se produce al combinar una elevada carga crónica con un A:C WL ratio muy alto. De forma similar, Bowen et al. (2017) concluyeron que la exposición crónica progresiva a mayores cargas, permitiendo facilitar los procesos de adaptación y recuperación, puede proteger a los jugadores de las lesiones mediante el desarrollo de su capacidad física. Además, los jugadores que disponen de buena capacidad física toleran mayores aumentos de la carga sin que suponga un incremento del riesgo de lesión (S. Malone et al., 2017).

Al analizar la evolución del fútbol en los últimos años, se ha observado una progresión hacia una mayor demanda en las respuestas físicas de los jugadores durante la competición. Comparado con años anteriores, ha aumentado el número total de acciones a alta intensidad, se realiza mayor distancia y número de carreras a máxima velocidad, los sprints son de menor recorrido (ha disminuido el recorrido de 7 a 6 metros de media) y más explosivos (Barnes et al., 2014; Bradley et al., 2016; Di Salvo et al., 2009). Además, en el fútbol más actual los jugadores realizan un mayor esfuerzo sin posesión de balón, mientras que la actividad de alta intensidad mostrada por los jugadores en posesión de balón y número de sprints de 10-20 metros no ha cambiado respecto a temporadas anteriores (Bradley et al., 2016; Di Salvo et al., 2009). En este contexto, tras analizar la actividad de TM de los equipos de la Premier League inglesa durante siete temporadas, desde la temporada 2006-2007 a la 2012-2013, Bradley et al. (2016) concluyeron que cada vez existe mayor igualdad en el rendimiento físico ofrecido por los jugadores de todos los equipos de la Premier, disminuyendo las diferencias entre los mejores y los peores equipos (según el ranking en la clasificación), y sugieren la importancia de considerar las acciones técnico-tácticas junto con las respuestas físicas de los jugadores. En la Tabla 3 se muestra la evolución del rendimiento en la Premier League desde la temporada 2006-2007 a la 2012-2013.

Tabla 3. Evolución rendimiento en la Premier League durante las temporadas 2006/07-2012/13 (Elaborado a partir de la información extraída de Bradley et al., 2016).

TIER-SPECIFIC EVOLUTION IN PREMIER LEAGUE											
Tier	PHYSICAL INDICATORS							TECHNICAL INDICATORS			
	HIR	HIR with Possesion	HIR without Poss.	SP Distance	Number of SP	Type of SP: Leading / Explosive	Averaged Distance of SP	Number of passes performed and received	% of successfull passes	Shorts & medium passes	Larges passes
A (1st-4th)	↑↑	↑	↑↑	↑↑	↑↑↑	L - ↑↑ Exp - ↑↑↑	↓	↑*	↑	↑↑	*
B (5th-8th)	↑↑	↑↑	↑↑	↑↑↑	↑↑↑	L - ↑↑ Exp - ↑↑↑	↓	↑↑↑	↑↑	↑↑*	↑*
C (9th-14th)	↑↑	↑	↑↑	↑↑	↑↑↑	L - ↑↑ Exp - ↑↑↑	↓	↑*	↑	↑↑	*
D (15th-20th)	↑↑	↑	↑↑	↑↑	↑↑↑	L - ↑↑ Exp - ↑↑↑	↓	↑*	↑↑	↑↑	*

(↑ - small increases / ↑↑ - moderate increases / ↑↑↑ - Large increases / ↑* - small-to-moderate increases / ↑↑* - moderate-to-large increases / ↓ - reduction / * - Minimal changes)

HIR, carrera de alta intensidad (≥ 19.8 km·h^{-1}); SP, sprint (≥ 25.1 km·h^{-1}); Explosive (Exp) sprint, carrera de sprint iniciada inmediatamente después de una carrera de baja-moderada velocidad (< 19.8 km·h^{-1}) en el periodo de 0.5 segundos previo; Leading (L) sprint, carrera de sprint iniciada tras una carrera de alta velocidad en los 0.5 segundos previos; Shorts & Mediums passes, pases de 1 a 25 metros; Long passes, pases de más de 25 metros.

Relación con los elementos técnicos y tácticos

En el fútbol profesional, existiendo cada vez más igualdad a nivel físico, los mejores equipos se diferencian del resto en que cuentan con un mayor porcentaje de éxito en las acciones técnico-tácticas (Bradley et al., 2016; Castellano, Casamichana, & Lago, 2012; Dellal et al., 2011). Por ejemplo, Dellal et al. (2011) identificaron una tasa de éxito de pases de más del 70% en el fútbol de élite, que posteriormente fue constatado Bradley et al. (2016), quienes observaron que sólo el 9% de todos los jugadores de la Premier League contaban con menos el 70% de éxito en los pases. Por tanto, tener un buen control y dominio de la técnica puede marcar la diferencia entre jugadores (Castañer et al., 2017). Sin embargo, existen autores que priorizan los aspectos tácticos sobre las acciones técnicas, argumentando que el desarrollo del componente táctico es fundamental en alto nivel para servir de apoyo a los jugadores en una correcta toma de decisiones y controlar las diferentes situaciones del partido con o sin posesión de balón (González-Víllora, Serra-Olivares, Pastor-Vicedo, & da Costa, 2015). De esta forma, jugadores con bajo nivel técnico, pero con buen entendimiento táctico pueden llegar al fútbol de alto nivel. En cambio, no se da la misma situación al revés; si los jugadores no tienen buen conocimiento táctico en un deporte complejo y cambiante como es el fútbol, no serán capaces de desarrollar adecuadamente sus habilidades (González-Víllora et al., 2015; Hughes & Bartlett, 2002).

Por otro lado, en función de la formación o sistema de juego que realice el equipo se demanda unas respuestas físicas específicas de los jugadores (Baptista et al., 2019; Carling, 2011; Tierney et al., 2016). Tierney et al. (2016) compararon el rendimiento físico entre las 5 formaciones de juego más comunes de la competición (4-4-2; 4-3-3; 3-5-2; 3-4-3 and 4-2-3-1) en futbolistas jóvenes de un equipo inglés de alto nivel, encontrando diferencias significativas entre formaciones. Por ejemplo, los jugadores realizaron mayor distancia total y distancia a alta intensidad en la formación 3-5-2, mientras que el mayor número de aceleraciones y desaceleraciones fue realizado con la formación 4-2-3-1. Por el contrario, otros autores no han encontrado diferencias significativas en el rendimiento físico de los jugadores en competición entre los diferentes sistemas de juego utilizado por un equipo a lo largo de la temporada (Baptista et al., 2019; Carling, 2011). En este sentido, sería interesante considerar el tiempo invertido durante las sesiones entrenamiento en preparar el nuevo sistema de juego, ya que las variaciones puntuales en la formación no son un estímulo suficiente para provocar cambios en las respuestas físicas de los jugadores, que necesitan un tiempo de aprendizaje y adaptación a las demandas específicas del sistema de juego nuevo (Hewitt, Greenham, & Norton, 2016).

Factores contextuales

El fútbol es un deporte complejo en el que el rendimiento físico de los jugadores es afectado por multitud de factores (Brito, Hertzog, & Nassis, 2016; Paul, Bradley, & Nassis, 2015; Rago, Rebelo, Krustrup, & Mohr, 2019; Stølen et al., 2005). Como se ha comentado anteriormente, variables situacionales como la posición de juego, el estilo de juego, o el TD del microciclo afectan al rendimiento físico de los jugadores, y por tanto deberían ser considerados en la monitorización de la carga. De la misma manera, las respuestas físicas de los jugadores pueden verse afectadas por factores contextuales tales como el periodo de la temporada, la calidad del equipo rival, la localización del partido o el resultado que se esté dando durante el partido, entre otros (Andrzejewski et al., 2018; Brito et al., 2016; Castellano et al., 2012; Chmura et al., 2018; Lago-Peñas, 2012; Rago et al., 2019). La mayoría de los autores han analizado el efecto de estos factores sobre las respuestas físicas mostradas por los jugadores durante el partido. Sin embargo, estudios más recientes han encontrado también efectos significativos de los factores contextuales en las respuestas físicas de los jugadores durante la semana de entrenamiento (Brito et al., 2016; Rago et al., 2019). De una manera u de otra, todos coinciden en la importancia de considerar los factores contextuales en la periodización y programación de la carga de los jugadores.

Periodo de la temporada

Los jugadores muestran respuestas físicas diferentes a lo largo de la temporada. Sin embargo, existe disconformidad en la literatura respecto a la carga realizada a lo largo de la temporada. J. Malone et al. (2015) encontraron que los jugadores cubrieron mayores distancias en las primeras etapas del periodo competitivo, y alcanzaron las mayores respuestas de frecuencia cardiaca (FC) a mediados de temporada, aunque sin suponer variaciones significativas de la carga. Otros autores han encontrado que conforme avanza la temporada, los jugadores muestran mayor distancia total y distancia de acciones a alta intensidad, dándose por tanto las mayores respuestas en el periodo final de la temporada (Mohr et al., 2003; E. Rampinini et al., 2007). Estas discrepancias entre autores pueden ser debidas a las diferentes ligas y países analizados; Mohr et al. (2003) y Rampinini et al. (2007) analizaron la Primera División italiana, mientras que J. Malone et al. (2015), la Premier League inglesa.

Calidad oponente

La calidad del equipo rival puede tener un gran efecto en las respuestas físicas desarrollada por los jugadores en competición (Castellano et al., 2011; Lago-Peñas et al., 2011; E. Rampinini et al., 2007). En general, la literatura ha mostrado que enfrentarse a los mejores equipos provoca una demanda física mayor, encontrando una distancia total y distancia de alta intensidad superior comparado a cuando se enfrentaban a equipos de menor calidad. Algunos autores argumentan que estas respuestas físicas aumentadas son debidas a variaciones en los aspectos técnico-tácticos (Castellano et al., 2011; Lago-Peñas, 2009). Por ejemplo, Lago-Peñas (2009) concluye que normalmente los mejores equipos cuentan con mayor posesión, consecuentemente enfrentarse a éstos implican correr una mayor distancia total sin posesión en el intento de recuperar el balón. Además, los mejores equipos son capaces de mover el balón más rápido o conseguir una mejor posición defensiva en el campo, por lo que se necesitan esfuerzos más intensos para conseguir desequilibrar al contrario (Yi et al., 2019).

Localización del partido

Jugar en casa o fuera también provoca diferentes respuestas físicas de los jugadores en competición (Lago-Peñas et al., 2011; Mohr et al., 2003). Los equipos que juegan en casa cubren una mayor distancia total y distancia de baja intensidad durante el partido. Sin embargo, las diferencias encontradas no implican variaciones en la distancia de alta intensidad. Por otro lado, estudios recientes han mostrado también diferentes respuestas físicas de los jugadores durante la semana de entrenamiento (Brito et al., 2016; Rago et al., 2019). Rago et al. (2019) encontraron un menor número de aceleraciones y desaceleraciones en la semana de entrenamiento previa a jugar un partido fuera de casa, mientras que Brito et al. (2016) encontraron mayor TL tras jugar un partido fuera, y una RPE mayor cuando había que preparar un partido en casa.

Marcador del partido

El resultado puede verse como una medida de consecución de rendimiento y, por tanto, puede influir en el esfuerzo realizado (Andrzejewski et al., 2018). Cuando los equipos juegan con un resultado adverso realizan un esfuerzo físico mayor que sus oponentes para intentar darle la vuelta al marcador (i.e., mayor número y distancia de actividad a alta intensidad) (Andrzejewski et al., 2018; Lago-Peñas, 2012; Lago-Peñas et al., 2011). De forma contraria, cuando los equipos tienen un resultado favorable normalmente adoptan una estrategia de retención de balón y bajan el ritmo, realizando consecuentemente menos esfuerzos. Por tanto, un resultado negativo implica un mayor desgaste físico de los jugadores durante el partido, lo que a su vez provoca un aumento de la fatiga durante y posteriormente al partido (Lago-Peñas et al., 2011).

Existen más factores que pueden afectar a las respuestas físicas de los jugadores y que por tanto deberían ser tenidos en cuenta en la programación de la carga de los jugadores con objeto de establecer un perfil físico más preciso, como la categoría o división en la que compitan (Bradley, Carling, et al., 2013), el estado anímico del jugador (González-Boto, Salguero, Tuero, Márquez, & Kellmann, 2008; McCall, Dupont, & Ekstrand, 2016; Op De Beéck et al., 2019; Saw, Main, & Gastin, 2016; Thorpe, Atkinson, Drust, & Gregson, 2017) o la calidad del sueño (Brink, Visscher, Coutts, & Lemmink, 2012; Carling et al., 2018; S. Malone et al., 2018; Silva et al., 2018; Thorpe et al., 2017;

Windt & Gabbett, 2017), entre otros. Como ha sido comentado anteriormente, mantener un adecuado control de la carga considerando todos estos factores es esencial para optimizar el rendimiento de los jugadores y prevenir lesiones (Gabbett, 2016; S. Malone et al., 2017; Owen et al., 2015). Sin embargo, en el fútbol de alto nivel lo más importante es ganar (Kattuman, Loch, & Kurchian, 2019), y a menudo los entrenadores, como responsables principales del equipo, son evaluados según los resultados que obtenga el equipo en competición (Castellano et al., 2012; Lago-Peñas, Lago-Ballesteros, Dellal, & Gómez, 2010). De acuerdo con esto, es una práctica común en alto nivel destituir al entrenador tras una racha negativa de resultados en el intento de revertir dicha situación (Balduck, Buelens, & Philippaerts, 2010; Heuer, Müller, Rubner, Hagemann, & Strauss, 2011; Lago-Peñas, 2011). Aunque este tópico se ha estudiado durante años, aún no está claro si el cambio de entrenador afecta al rendimiento del equipo. De una manera o de otra, en alto nivel los jugadores precisan una capacidad física excelente para hacer frente a las altas exigencias de la competición y poder desarrollar las habilidades técnicas y aspectos tácticos de forma eficiente en cualquier contexto o escenario. Por tanto, la monitorización y control de la carga física de entrenamiento y competición considerando los posibles factores que puedan afectar a ésta es esencial en el fútbol (Barnes et al., 2014; Bradley et al., 2016).

VI. Referencias Bibliográficas

Referencias bibliográficas

Abade, E., Sampaio, J., Gonçalves, B., Baptista, J., Alves, A., & Viana, J. (2017). Effects of different re-warm up activities in football players' performance. *PLOS ONE*, *12*(6), e0180152. https://doi.org/10.1371/journal.pone.0180152

Abt, G., & Lovell, R. (2009). The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. *Journal of Sports Sciences*, *27*(9), 893–898. https://doi.org/10.1080/02640410902998239

Ade, J., Fitzpatrick, J., & Bradley, P. S. (2016). High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills. *Journal of Sports Sciences*, *34*(24), 2205–2214. https://doi.org/10.1080/02640414.2016.1217343

Al Haddad, H., Simpson, B. M., Buchheit, M., Di Salvo, V., & Mendez-Villanueva, A. (2015). Peak match speed and maximal sprinting speed in young soccer players: Effect of age and playing position. *International Journal of Sports Physiology and Performance*, *10*(7), 888–896. https://doi.org/10.1123/ijspp.2014-0539

Alexandre, D., da Silva, C. D., Hill-Haas, S., Wong, D. P., Natali, A. J., De Lima, J. R. P., … Karim, C. (2012). Heart rate monitoring in soccer: interest and limits during competitive match play and training, practical application. *Journal of Strength and Conditioning Research*, *26*(10), 2890–2906. https://doi.org/10.1519/JSC.0b013e3182429ac7

Andrzejewski, M., Chmura, J., Pluta, B., Strzelczyk, R., & Kasprzak, A. (2013). Analysis of Sprinting Activities of Professional Soccer Players. *Journal of Strength and Conditioning Research*, *27*(8), 2134–2140. https://doi.org/10.1519/JSC.0b013e318279423e

Andrzejewski, M., Chmura, P., Konefał, M., Kowalczuk, E., & Chmura, J. (2018). Match outcome and sprinting activities in match play by elite German soccer players. *The Journal of Sports Medicine and Physical Fitness*, *58*(6), 785–792. https://doi.org/10.23736/S0022-4707.17.07352-2

Balduck, A.-L., Buelens, M., & Philippaerts, R. (2010). Short-Term Effects of Midseason Coach Turnover on Team Performance in Soccer. *Research Quarterly for Exercise and Sport*, *81*(3), 379–383. https://doi.org/10.1080/02701367.2010.10599686

Bangsbo, J., Mohr, M., & Krustrup, P. (2006). Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences*, *24*(7), 665–674. https://doi.org/10.1080/02640410500482529

Bangsbo, J., Nørregaard, L., & Thorsø, F. (1991). Activity profile of competition soccer. *Canadian Journal of Sport Sciences = Journal Canadien Des Sciences Du Sport*, *16*(2), 110–116.

Baptista, I., Johansen, D., Figueiredo, P., Rebelo, A., & Pettersen, S. A. (2019). A comparison of match-physical demands between different tactical systems: 1-4-5-1 vs 1-3-5-2. *PLoS ONE*, *14*(4), 1–4. https://doi.org/10.1371/journal.pone.0214952

Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The Evolution of Physical and Technical Performance. *International Journal of Sports Medicine*, *35*(13), 1095–1100.

Blanch, P., & Gabbett, T. J. (2015). Has the athlete trained enough to return to play safely? The acute:chronic workload ratio permits clinicians to quantify a player's risk of subsequent injury. *British Journal of Sports Medicine*, *50*(8), 471–475. https://doi.org/10.1136/bjsports-2015-095445

Bowen, L., Gross, A. S., Gimpel, M., & Li, F.-X. (2017). Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. *British Journal of Sports Medicine*, *51*(5), 452–459. https://doi.org/10.1136/bjsports-2015-095820

Bradley, P. S., & Ade, J. D. (2018). Are Current Physical Match Performance Metrics in Elite Soccer Fit for Purpose or Is the Adoption of an Integrated Approach Needed? *International Journal of Sports Physiology and Performance*, *13*(5), 656–664. https://doi.org/10.1123/ijspp.2017-0433

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

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

Bradley, P. S., Lago-Peñas, C., & Rey, E. (2014). Evaluation of the Match

Performances of Substitution Players in Elite Soccer. *International Journal of Sports Physiology and Performance*, *9*(3), 415–424. https://doi.org/10.1123/ijspp.2013-0304

Bradley, P. S., Lago-Peñas, C., Rey, E., & Gomez Diaz, A. (2013). The effect of high and low percentage ball possession on physical and technical profiles in English FA Premier League soccer matches. *Journal of Sports Sciences*, *31*(12), 1261–1270. https://doi.org/10.1080/02640414.2013.786185

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

Brink, M. S., Visscher, C., Coutts, A. J., & Lemmink, K. A. P. M. (2012). Changes in perceived stress and recovery in overreached young elite soccer players. *Scandinavian Journal of Medicine and Science in Sports*, *22*(2), 285–292. https://doi.org/10.1111/j.1600-0838.2010.01237.x

Brito, J., Hertzog, M., & Nassis, G. P. (2016). Do Match-Related Contextual Variables Influence Training Load in Highly Trained Soccer Players? *Journal of Strength and Conditioning Research*, *30*(2), 393–399. https://doi.org/10.1519/JSC.0000000000001113

Buchheit, M., Allen, A., Poon, T. K., Modonutti, M., Gregson, W., & Di Salvo, V. (2014). Integrating different tracking systems in football: multiple camera semi-automatic system, local position measurement and GPS technologies. *Journal of Sports Sciences*, *32*(20), 1844–1857. https://doi.org/10.1080/02640414.2014.942687

Cardinale, M., & Varley, M. C. (2017). Wearable Training-Monitoring Technology: Applications, Challenges, and Opportunities. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), S255–S262. https://doi.org/10.1123/ijspp.2016-0423

Carling, C. (2011). Influence of opposition team formation on physical and skill-related performance in a professional soccer team. *European Journal of Sport Science*, *11*(3), 155–164. https://doi.org/10.1080/17461391.2010.499972

Carling, C. (2013). Interpreting physical performance in professional soccer match-play: Should we be more pragmatic in our approach? *Sports Medicine*, *43*(8), 655–663. https://doi.org/10.1007/s40279-013-0055-8

Carling, C., Bradley, P. S., McCall, A., & Dupont, G. (2016). Match-to-match variability in high-speed running activity in a professional soccer team. *Journal of Sports Sciences*, *34*(24), 2215–2223. https://doi.org/10.1080/02640414.2016.1176228

Carling, C., Lacome, M., McCall, A., Dupont, G., Le Gall, F., Simpson, B., & Buchheit, M. (2018). Monitoring of Post-match Fatigue in Professional Soccer: Welcome to the Real World. *Sports Medicine*, *48*(12), 2695–2702. https://doi.org/10.1007/s40279-018-0935-z

Carling, C., Le Gall, F., & Dupont, G. (2012). Are physical performance and injury risk in a professional soccer team in match-play affected over a prolonged period of fixture congestion? *International Journal of Sports Medicine*, *33*(1), 36–42. https://doi.org/10.1055/s-0031-1283190

Castagna, C., Varley, M., Póvoas, S. C. A., & D'Ottavio, S. (2017). Evaluation of the Match External Load in Soccer: Methods Comparison. *International Journal of Sports Physiology and Performance*, *12*(4), 490–495. https://doi.org/10.1123/ijspp.2016-0160

Castañer, M., Barreira, D., Camerino, O., Anguera, M. T., Fernandes, T., & Hileno, R. (2017). Mastery in Goal Scoring, T-Pattern Detection, and Polar Coordinate Analysis of Motor Skills Used by Lionel Messi and Cristiano Ronaldo. *Frontiers in Psychology*, *8*(MAY), 741. https://doi.org/10.3389/fpsyg.2017.00741

Castellano, J., Blanco-Villaseñor, A., & Álvarez, D. (2011). Contextual Variables and Time-Motion Analysis in Soccer. *International Journal of Sports Medicine*, *32*(06), 415–421. https://doi.org/10.1055/s-0031-1271771

Castellano, J., Casamichana, D., & Lago, C. (2012). The Use of Match Statistics that Discriminate Between Successful and Unsuccessful Soccer Teams. *Journal of Human Kinetics*, *31*(1), 139–147. https://doi.org/10.2478/v10078-012-0015-7

Castillo-Rodríguez, A., Cano-Cáceres, F. J., Figueiredo, A., & Fernández-García, J. C. (2020). Train Like You Compete? Physical and Physiological Responses on Semi-Professional Soccer Players. *International Journal of Environmental Research and Public Health*, *17*(3), 756. https://doi.org/10.3390/ijerph17030756

Chmura, P., Konefał, M., Chmura, J., Kowalczuk, E., Zajac, T., Rokita, A., & Andrzejewski, M. (2018). Match outcome and running performance in different intensity ranges among elite soccer players. *Biology of Sport*, *35*(2), 197–203.

https://doi.org/10.5114/biolsport.2018.74196

Clemente, F. M., Owen, A. L., Serra-Olivares, J., Nikolaidis, P. T., Van Der Linden, C. M. I., & Mendes, B. (2019). Characterization of the Weekly External Load Profile of Professional Soccer Teams from Portugal and the Netherlands. *Journal of Human Kinetics*, *66*(1), 155–164. https://doi.org/10.2478/hukin-2018-0054

Clemente, F. M., Rabbani, A., Conte, D., Castillo, D., Afonso, J., Clark, C. C. T., … Knechtle, B. (2019). Training/match external load ratios in professional soccer players: A full-season study. *International Journal of Environmental Research and Public Health*, *16*(17), 1–11. https://doi.org/10.3390/ijerph16173057

Dalen, T., Jørgen, I., Gertjan, E., Geir Havard, H., & Ulrik, W. (2016). Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer. *Journal of Strength and Conditioning Research*, *30*(2), 351–359. https://doi.org/10.1519/JSC.0000000000001063

Dellal, A., Chamari, K., Wong, D. P., Ahmaidi, S., Keller, D., Barros, R., … Carling, C. (2011). Comparison of physical and technical performance in European soccer match-play: Fa Premier League and La Liga. *European Journal of Sport Science*, *11*(1), 51–59. https://doi.org/10.1080/17461391.2010.481334

Dellal, A., Lago-Peñas, C., Rey, E., Chamari, K., & Orhant, E. (2015). The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *British Journal of Sports Medicine*, *49*(6), 390–394. https://doi.org/10.1136/bjsports-2012-091290

Di Mascio, M., & Bradley, P. S. (2013). Evaluation of the most intense high-intensity running period in English FA premier league soccer matches. *Journal of Strength and Conditioning Research*, *27*(4), 909–915. https://doi.org/10.1519/JSC.0b013e31825ff099

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of High Intensity Activity in Premier League Soccer. *International Journal of Sports Medicine*, *30*(03), 205–212. https://doi.org/10.1055/s-0028-1105950

Djaoui, L., Wong, D. P., Pialoux, V., Hautier, C., Da Silva, C. D., Chamari, K., & Dellal, A. (2014). Physical Activity during a Prolonged Congested Period in a Top-Class European Football Team. *Asian Journal of Sports Medicine*, *5*(1), 47–53. https://doi.org/10.5812/asjsm.34233

Dupont, G., Nedelec, M., McCall, A., McCormack, D., Berthoin, S., & Wisløff, U.

(2010). Effect of 2 soccer matches in a week on physical performance and injury rate. *American Journal of Sports Medicine*, *38*(9), 1752–1758. https://doi.org/10.1177/0363546510361236

Ehrmann, F. E., Duncan, C. S., Sindhusake, D., Franzsen, W. N., & Greene, D. A. (2016). GPS and Injury Prevention in Professional Soccer. *Journal of Strength and Conditioning Research*, *30*(2), 360–367. https://doi.org/10.1519/JSC.0000000000001093

Gabbett, T. J. (2016). The training—injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine*, *50*(5), 273–280. https://doi.org/10.1136/bjsports-2015-095788

Gabbett, T. J., Hulin, B. T., Blanch, P., & Whiteley, R. (2016). High training workloads alone do not cause sports injuries: how you get there is the real issue. *British Journal of Sports Medicine*, *50*(8), 444–445. https://doi.org/10.1136/bjsports-2015-095567

Gabbett, T. J., Nassis, G. P., Oetter, E., Pretorius, J., Johnston, N., Medina, D., … Ryan, A. (2017). The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data. *British Journal of Sports Medicine*, *51*(20), 1451–1452. https://doi.org/10.1136/bjsports-2016-097298

Gaudino, P., Iaia, F. M., Alberti, G., Hawkins, R. D., Strudwick, A. J., & Gregson, W. (2014). Systematic bias between running speed and metabolic power data in elite soccer players: Influence of drill type. *International Journal of Sports Medicine*, *35*(6), 489–493. https://doi.org/10.1055/s-0033-1355418

Gaudino, P., Iaia, F. M., Alberti, G., Strudwick, A. J., Atkinson, G., & Gregson, W. (2013). Monitoring training in elite soccer players: systematic bias between running speed and metabolic power data. *International Journal of Sports Medicine*, *34*(11), 963–968. https://doi.org/10.1055/s-0033-1337943

Giménez, J. V., Leicht, A. S., & Gomez, M. A. (2019). Physical Performance Differences Between Starter and Non-Starter Players During Professional Soccer Friendly Matches. *Journal of Human Kinetics*, *69*(1), 283–291. https://doi.org/10.2478/hukin-2019-0018

González-Boto, R., Salguero, A., Tuero, C., Márquez, S., & Kellmann, M. (2008). Spanish adaptation and analysis by structural equation modeling of an instrument for monitoring overtraining: the recovery-stress questionnaire (RestQ-Sport).

Social Behavior and Personality: An International Journal, *36*(5), 635–650.

González-Víllora, S., Serra-Olivares, J., Pastor-Vicedo, J. C., & da Costa, I. T. (2015). Review of the tactical evaluation tools for youth players, assessing the tactics in team sports: football. *SpringerPlus*, *4*(1), 1–17. https://doi.org/10.1186/s40064-015-1462-0

Gregson, W., Drust, B., Atkinson, G., & Salvo, V. (2010). Match-to-Match Variability of High-Speed Activities in Premier League Soccer. *International Journal of Sports Medicine*, *31*(04), 237–242. https://doi.org/10.1055/s-0030-1247546

Grünbichler, J., Federolf, P., & Gatterer, H. (2019). Workload efficiency as a new tool to describe external and internal competitive match load of a professional soccer team: A descriptive study on the relationship between pre-game training loads and relative match load. *European Journal of Sport Science*, *0*(0), 1–17. https://doi.org/10.1080/17461391.2019.1697374

Gualtieri, A., Rampinini, E., Sassi, R., & Beato, M. (2020). Workload monitoring in top-level soccer players during congested fixture periods. *International Journal of Sports Medicine*, ahead of print. https://doi.org/10.1055/a-1171-1865

Hader, K., Rumpf, M. C., Hertzog, M., Kilduff, L. P., Girard, O., & Silva, J. R. (2019). Monitoring the Athlete Match Response: Can External Load Variables Predict Post-match Acute and Residual Fatigue in Soccer? A Systematic Review with Meta-analysis. *Sports Medicine - Open*, *5*(1). https://doi.org/10.1186/s40798-019-0219-7

Heuer, A., Müller, C., Rubner, O., Hagemann, N., & Strauss, B. (2011). Usefulness of dismissing and changing the coach in professional soccer. *PLoS ONE*, *6*(3), 1–7. https://doi.org/10.1371/journal.pone.0017664

Hewitt, A., Greenham, G., & Norton, K. (2016). Game style in soccer: what is it and can we quantify it? *International Journal of Performance Analysis in Sport*, *16*(1), 355–372. https://doi.org/10.1080/24748668.2016.11868892

Hoppe, M. W., Baumgart, C., Polglaze, T., & Freiwald, J. (2018). Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports. *PLOS ONE*, *13*(2), e0192708. https://doi.org/10.1371/journal.pone.0192708

Hughes, M. D., & Bartlett, R. M. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences*, *20*(10), 739–754.

https://doi.org/10.1080/026404102320675602

Hulin, B. T., Gabbett, T. J., Lawson, D. W., Caputi, P., & Sampson, J. A. (2016). The acute: Chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. *British Journal of Sports Medicine*, *50*(4), 231–236. https://doi.org/10.1136/bjsports-2015-094817

Kattuman, P., Loch, C., & Kurchian, C. (2019). Management succession and success in a professional soccer team. *PLoS ONE*, *14*(3), 1–20. https://doi.org/10.1371/journal.pone.0212634

Kelly, V. G., Rabitohs, S. S., & Coutts, A. J. (2007). Planning and monitoring training loads during the competition phase in Team Sports. *Strength and Conditioning Journal*, *29*(4), 32–37.

Lago-Peñas, C. (2009). The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *Journal of Sports Sciences*, *27*(13), 1463–1469. https://doi.org/10.1080/02640410903131681

Lago-Peñas, C. (2011). Coach Mid-Season Replacement and Team Performance in Professional Soccer. *Journal of Human Kinetics*, *28*(1), 115–122. https://doi.org/10.2478/v10078-011-0028-7

Lago-Peñas, C. (2012). The Role of Situational Variables in Analysing Physical Performance in Soccer. *Journal of Human Kinetics*, *35*(1), 89–95. https://doi.org/10.2478/v10078-012-0082-9

Lago-Peñas, C., Lago-Ballesteros, J., Dellal, A., & Gómez, M. (2010). Game-Related Statistics that Discriminated Winning, Drawing and Losing Teams from the Spanish Soccer League. *Journal of Sports Science & Medicine*, *9*(2), 288–293.

Lago-Peñas, C., Rey, E., Lago-Ballesteros, J., Casáis, L., & Domínguez, E. (2011). The Influence of a Congested Calendar on Physical Performance in Elite Soccer. *Journal of Strength and Conditioning Research*, *25*(8), 2111–2117. https://doi.org/10.1519/JSC.0b013e3181eccdd2

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

Malone, J., Lovell, R., Varley, M. C., & Coutts, A. J. (2017). Unpacking the Black Box:

Applications and Considerations for Using GPS Devices in Sport. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), S2-18-S2-26. https://doi.org/10.1123/ijspp.2016-0236

Malone, S., Owen, A. L., Newton, M., Mendes, B., Collins, K. D., & Gabbett, T. J. (2017). The acute:chonic workload ratio in relation to injury risk in professional soccer. *Journal of Science and Medicine in Sport*, *20*(6), 561–565. https://doi.org/10.1016/j.jsams.2016.10.014

Malone, S., Owen, A. L., Newton, M., Mendes, B., Tiernan, L., Hughes, B., & Collins, K. (2018). Wellbeing perception and the impact on external training output among elite soccer players. *Journal of Science and Medicine in Sport*, *21*(1), 29–34. https://doi.org/10.1016/j.jsams.2017.03.019

Martín-García, A., Gómez Díaz, A., Bradley, P. S., Morera, F., & Casamichana, D. (2018). Quantification of a professional football team's external load using a microcycle structure. *Journal of Strength and Conditioning Research*, *32*(12), 3511–3518. https://doi.org/10.1519/jsc.0000000000002816

Martín-López, Á., Mendes, R. S., & Castillo-Rodríguez, A. (2018). Internal and External Loads in Training Week Before the Competition in U19 High-Level Soccer Players. *Journal of Strength and Conditioning Research*, *00*(00), 1–7. https://doi.org/10.1519/JSC.0000000000002975

McCall, A., Dupont, G., & Ekstrand, J. (2016). Injury prevention strategies, coach compliance and player adherence of 33 of the UEFA Elite Club Injury Study teams: A survey of teams' head medical officers. *British Journal of Sports Medicine*, *50*(12), 725–730. https://doi.org/10.1136/bjsports-2015-095259

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

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

Nassis, G. P., & Gabbett, T. J. (2017). Is workload associated with injuries and performance in elite football? A call for action. *British Journal of Sports Medicine*, *51*(6), 486–487. https://doi.org/10.1136/bjsports-2016-095988

Oliveira, R., Brito, J., Martins, A., Mendes, B., Calvete, F., Carriço, S., … Marques, M.

C. (2019). In-season training load quantification of one-, two- and three-game week schedules in a top European professional soccer team. *Physiology and Behavior*, *201*(October 2018), 146–156. https://doi.org/10.1016/j.physbeh.2018.11.036

Op De Beéck, T., Jaspers, A., Brink, M. S., Frencken, W. G. P., Staes, F., Davis, J. J., & Helsen, W. F. (2019). Predicting Future Perceived Wellness in Professional Soccer: The Role of Preceding Load and Wellness. *International Journal of Sports Physiology and Performance*, *14*(8), 1074–1080. https://doi.org/10.1123/ijspp.2017-0864

Osgnach, C., & Di Prampero, P. E. (2018). Metabolic Power in Team Sports - Part 2: Aerobic and Anaerobic Energy Yields. *International Journal of Sports Medicine*, *39*(08), 588–595. https://doi.org/10.1055/a-0592-7219

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: A new match analysis approach. *Medicine and Science in Sports and Exercise*, *42*(1), 170–178. https://doi.org/10.1249/MSS.0b013e3181ae5cfd

Owen, A. L., Djaoui, L., Newton, M., Malone, S., & Mendes, B. (2017). A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer. *Science and Medicine in Football*, *3938*(July), 1–6. https://doi.org/10.1080/24733938.2017.1334958

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

Owen, A. L., Forsyth, J. J., Wong, D. P., Dellal, A., Connelly, S. P., & Chamari, K. (2015). Heart Rate–Based Training Intensity and Its Impact on Injury Incidence Among Elite-Level Professional Soccer Players. *Journal of Strength and Conditioning Research*, *29*(6), 1705–1712. https://doi.org/10.1519/JSC.0000000000000810

Owen, A. L., Lago-Peñas, C., Gómez, M. Á., Mendes, B., & Dellal, A. (2017). Analysis of a training mesocycle and positional quantification in elite European soccer players. *International Journal of Sports Science and Coaching*, *12*(5), 665–676.

https://doi.org/10.1177/1747954117727851

Paul, D. J., Bradley, P. S., & Nassis, G. P. (2015). Factors Affecting Match Running Performance of Elite Soccer Players: Shedding Some Light on the Complexity. *International Journal of Sports Physiology and Performance*, *10*(4), 516–519. https://doi.org/10.1123/ijspp.2015-0029

Polglaze, T., Dawson, B., & Peeling, P. (2016). Gold Standard or Fool's Gold? The Efficacy of Displacement Variables as Indicators of Energy Expenditure in Team Sports. *Sports Medicine*, *46*(5), 657–670. https://doi.org/10.1007/s40279-015-0449-x

Polglaze, T., & Hoppe, M. W. (2019). Metabolic Power: A Step in the Right Direction for Team Sports. *International Journal of Sports Physiology and Performance*, *14*(3), 407–411. https://doi.org/10.1123/ijspp.2018-0661

Pons, E., García-Calvo, T., Resta, R., Blanco, H., del Campo, R. L., García, J. D., & Pulido, J. J. (2019). A comparison of a GPS device and a multi-camera video technology during official soccer matches: Agreement between systems. *PLoS ONE*, *14*(8), 1–12. https://doi.org/10.1371/journal.pone.0220729

Rago, V., Rebelo, A., Krustrup, P., & Mohr, M. (2019). Contextual Variables and Training Load Throughout a Competitive Period in a Top-Level Male Soccer Team. *Journal of Strength and Conditioning Research*, *Publish Ah*(25), 1. https://doi.org/10.1519/JSC.0000000000003258

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. (2007). Variation in Top Level Soccer Match Performance. *International Journal of Sports Medicine*, *28*(12), 1018–1024. https://doi.org/10.1055/s-2007-965158

Rampinini, Ermanno, Impellizzeri, F. M., Castagna, C., Coutts, A. J., & Wisløff, U. (2009). Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *Journal of Science and Medicine in Sport*, *12*(1), 227–233. https://doi.org/10.1016/j.jsams.2007.10.002

Robertson, S., Bartlett, J. D., & Gastin, P. B. (2017). Red, Amber, or Green? Athlete Monitoring in Team Sport: The Need for Decision-Support Systems. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), S2-73-S2-79. https://doi.org/10.1123/ijspp.2016-0541

Saw, A. E., Main, L. C., & Gastin, P. B. (2016). Monitoring the athlete training response: Subjective self-reported measures trump commonly used objective measures: A systematic review. *British Journal of Sports Medicine*, *50*(5), 281–291. https://doi.org/10.1136/bjsports-2015-094758

Seirul-lo, F., Tous, J., Solé, J., Moras, G., Massafret, M., Espar, X., … Padullés, J. M. (2017). *El entrenamiento en los deportes de equipo* (1ª Edición). Barcelona, España: Ed. Mastercede: 131-144.

Silva, J. R., Rumpf, M. C., Hertzog, M., Castagna, C., Farooq, A., Girard, O., & Hader, K. (2018). Acute and Residual Soccer Match-Related Fatigue: A Systematic Review and Meta-analysis. In *Sports Medicine* (Vol. 48). https://doi.org/10.1007/s40279-017-0798-8

Sparks, M., Coetzee, B., & Gabbett, T. J. (2016). Variations in high-intensity running and fatigue during semi-professional soccer matches. *International Journal of Performance Analysis in Sport*, 122–132.

Stevens, T. G. A., de Ruiter, C. J., Twisk, J. W. R., Savelsbergh, G. J. P., & Beek, P. J. (2017). Quantification of in-season training load relative to match load in professional Dutch Eredivisie football players. *Science and Medicine in Football*, *1*(2), 117–125. https://doi.org/10.1080/24733938.2017.1282163

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Medicine (Auckland, N.Z.)*, *35*(6), 501–536.

Suarez-Arrones, L., Torreño, N., Requena, B., Sáez De Villarreal, E., Casamichana, D., Barbero-Alvarez, J. C., & Munguía-Izquierdo, D. (2015). Match-play activity profile in professional soccer players during official games and the relationship between external and internal load. *The Journal of Sports Medicine and Physical Fitness*, *55*(12), 1417–1422.

Terziotti, P., Sim, M., & Polglaze, T. (2018). A comparison of displacement and energetic variables between three team sport GPS devices. *International Journal of Performance Analysis in Sport*, *18*(5), 823–834. https://doi.org/10.1080/24748668.2018.1525650

Theodoropoulos, J. S., Bettle, J., & Kosy, J. D. (2020). The use of GPS and inertial devices for player monitoring in team sports: A review of current and future applications. *Orthopedic Reviews*, *12*(1), 1–7. https://doi.org/10.4081/or.2020.7863

Thorpe, R. T., Atkinson, G., Drust, B., & Gregson, W. (2017). Monitoring Fatigue Status in Elite Team-Sport Athletes: Implications for Practice. *International Journal of Sports Physiology and Performance*, *12*(Suppl 2), S2-27-S2-34.

https://doi.org/10.1123/ijspp.2016-0434

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

Turner, A. N., & Stewart, P. F. (2014). Strength and conditioning for soccer players. *Strength and Conditioning Journal*, *36*(4), 1–13. https://doi.org/10.1519/SSC.0000000000000054

Vigne, G., Gaudino, C., Rogowski, I., Alloatti, G., & Hautier, C. (2010). Activity profile in elite Italian soccer team. *International Journal of Sports Medicine*, *31*(5), 304–310. https://doi.org/10.1055/s-0030-1248320

Vigne, Gregory, Dellal, A., Gaudino, C., Chamari, K., Rogowski, I., Alloatti, G., … Hautier, C. (2013). Physical Outcome in a Successful Italian Serie A Soccer Team Over Three Consecutive Seasons. *Journal of Strength and Conditioning Research*, *27*(5), 1400–1406. https://doi.org/10.1519/JSC.0b013e3182679382

Windt, J., & Gabbett, T. J. (2017). How do training and competition workloads relate to injury? the workload - Injury aetiology model. *British Journal of Sports Medicine*, *51*(5), 428–435. https://doi.org/10.1136/bjsports-2016-096040

Yi, Q., Gómez, M. A., Wang, L., Huang, G., Zhang, H., & Liu, H. (2019). Technical and physical match performance of teams in the 2018 FIFA World Cup: Effects of two different playing styles. *Journal of Sports Sciences*, *37*(22), 2569–2577. https://doi.org/10.1080/02640414.2019.1648120

VII. Objetivos e Hipótesis

Las altas exigencias físicas requeridas en el fútbol profesional junto con la complejidad del proceso de entrenamiento despiertan un gran interés en la literatura científica actual en la búsqueda de un mejor sistema de control y monitorización de la carga que consiga optimizar la capacidad física de los jugadores sin incurrir en un mayor riesgo de lesión. Con el planteamiento de la presente Tesis Doctoral se pretende aportar nuevos conocimientos que ayuden a comprender y mejorar la planificación y monitorización de la carga externa de los jugadores desde una perspectiva práctica, y de esta manera puedan servir de ayuda a preparadores físicos y entrenadores para optimizar la capacidad física de los jugadores.

Objetivos

El **objetivo general** de esta Tesis Doctoral radica en el análisis y estudio de las respuestas físicas basadas en la actividad de locomoción realizadas por futbolistas profesionales integrantes de equipos españoles de Primera, Segunda y Segunda División 'B' a lo largo de una temporada, en función de la posición de juego y del efecto de los factores contextuales que puedan condicionar el rendimiento de los jugadores, con objeto de constatar si la carga realizada en entrenamiento se ajusta la carga exigida en competición.

A partir del objetivo general surgen diversos **objetivos específicos** que se corresponden con los objetivos de cada uno de los estudios:

1. Analizar las respuestas físicas en entrenamiento de futbolistas profesionales considerando el efecto de los factores contextuales localización del partido[2], periodo de la temporada[3] y calidad del equipo rival[4] (estudio 1).
2. Establecer modelos de predicción de las respuestas físicas en entrenamiento considerando el efecto de los factores contextuales (estudio 1).

[2] La localización del partido se refiere a jugar en 'casa' (i.e., estadio del propio equipo) o 'fuera' (i.e., campo del equipo rival).
[3] La temporada se divide en periodo inicial, medio y final (explicado con mayor detalle en 'Material & Métodos').
[4] La calidad del rival se establece en función de su posición en el ranking diferenciando entre equipo top, medio y débil (explicado con mayor detalle en 'Material & Métodos').

3. Analizar cómo influye el cambio de entrenador a mediados de temporada en las respuestas físicas de los futbolistas (estudio 2).
4. Examinar si el rendimiento físico que realizan los jugadores durante la semana de entrenamiento es predictor de las respuestas físicas que muestren en el partido siguiente (estudio 3)
5. Ganar conocimiento sobre la repercusión y efectos a corto y largo plazo en el rendimiento físico y la incidencia de lesiones de futbolistas profesionales que puede ocasionar el periodo de cuarentena por coronavirus una vez retomen la actividad[5] (estudio 4).

[5] Este objetivo surge de forma imprevista ante la insólita situación de una pandemia mundial vivida durante el año 2020 en la que gobiernos de todo el mundo activaron el estado de alarma y toda la población tuvo que confinarse en sus casas, parando todas las competiciones y entrenamientos en todo el mundo.

Hipótesis

La **hipótesis general** de esta Tesis Doctoral sostiene que la carga realizada por los jugadores en entrenamiento no se corresponde con las demandas de la competición.

Sin embargo, esto es una suposición muy amplia y genérica y, por tanto, se postulan hipótesis más concretas que responden a los objetivos específicos planteados anteriormente.

Hipótesis específicas:

1. Los jugadores muestran respuestas físicas mayores durante la semana de entrenamiento que precede un partido ante un equipo top o fuera de casa. Además, la actividad también es mayor durante el periodo inicial de la temporada en comparación con el periodo medio y final.
2. El contexto en el que tenga lugar el partido afecta al rendimiento físico que muestran los jugadores durante la semana de entrenamiento previa.
3. El cambio de entrenador a mediados de temporada puede suponer un estímulo positivo para los jugadores y, por tanto, reflejarse en un aumento del rendimiento físico con el nuevo entrenador.
4. La carga realizada por los jugadores durante la semana de entrenamiento es predictor del rendimiento físico que mostrarán los futbolistas en el partido siguiente.
5. El rendimiento físico de los futbolistas va a verse fuertemente afectado durante la vuelta a la actividad a corto y medio plazo tras el periodo de cuarentena, resultando en un aumento de la incidencia de lesiones.

VIII. Objectives & Hypothesis

The high physical demands of professional soccer together with the complexity of the training process has led to a great interest in current scientific research in the search for improving the load monitoring to optimize the players' physical capacity without increasing the injury incidence. This Doctoral Thesis aims to provide new knowledge for the improvement of the workload periodization and programming of the players from a practical approach and thus may assist athletic trainers and coaches to optimize the physical capacity of the players.

Objectives

The **general objective** of this Thesis is to analyse and study the TM activity showed by professional soccer players competing in the Spanish First, Second and Second B division across the season, according to the playing position and several contextual factors that may affect the players' performance and thus analyse whether the workload performed in training is adequate to cope with the match demands.

The general objective gives rise to several **specific objectives** that correspond to the aims of each of the studies:

1. Analyse the physical responses of professional soccer players considering the effect of contextual factors match location[6], season period[7] and quality of the opponent[8] (study 1).
2. Identify predictive models of physical responses in professional soccer players taking into account the effect of contextual factors (study 1).
3. Analyse the effect of mid-season coach turnover on players' physical performance (study 2).
4. Examine whether the physical performance performed by professional players during the training week can predict physical responses in the following match (study 3).

[6] The match location refers to playing at home (i.e., the team's stadium) or away (i.e., the opposing team's stadium).
[7] The season is divided into initial, middle and final period (explained in detail in 'Material & Methods').
[8] The quality of the opponent is established according to its ranking in the table, differentiating between top, middle and weak teams (explained in detail in 'Material & Methods').

5. Gaining knowledge about the potential effects of short- and long-term coronavirus lockdown on physical performance and injury incidence in high-level soccer players once teams return to training and competition[9] (study 4).

[9] This objective arises unexpectedly due to the unprecedent global pandemic during the year 2020 in which governments around the world have been forced to activate a state of lockdown, thus stopping all competitions and training sessions worldwide.

Hypothesis

The **general hypothesis** of this Thesis is that the TL does not correspond to the competition demands.

However, this is quite broad and generic assumption and, therefore, specific hypotheses are postulated which respond to the specific objectives described above.

Specific hypotheses:

1. Players show higher physical responses during the training week prior to an away-match or playing against a top team. In addition, players also show higher responses in the initial period of the season compared to the middle and final periods.
2. The match-specific context affects the players' physical performance on the previous training week.
3. The mid-season coach turnover may be can provide a positive stimulus for players and, consequently, be reflected in an increased physical performance with the new coach.
4. The players' ML can be predicted from the workload performed by players throughout the previous training week.
5. The physical performance of players will be strongly affected in the short- and medium-term after the coronavirus lockdown, resulting in an increased incidence of injury.

IX. Material & Métodos

Material & Métodos

Esta Tesis Doctoral ha sido realizada por compendio de artículos, con cuatro estudios diferenciados. A excepción del estudio referido al efecto del cese de actividad causado por periodo de cuarentena del coronavirus[10] en el rendimiento físico de futbolistas profesionales, que en forma lógica no estaba contemplado entre los objetivos iniciales de la tesis y presenta una metodología diferente a los demás artículos, los estudios que componen este trabajo fueron elaborados a partir de los registros de diferentes actividades de locomoción de futbolistas profesionales de tres equipos españoles pertenecientes a las categorías de Primera División, Segunda División y Segunda División 'B' recogidos en entrenamiento y competición oficial a lo largo de una temporada mediante el sistema de monitorización GPS (GPEXE® 20 Hz, Exelio srl, Udine, Italy). De forma generalizada, se han realizado estudios observacionales retrospectivos con un diseño de tipo comparativo e inferencial, con diferencia de medidas intra e inter-sujeto. De esta manera, jugadores y cuerpo técnico han desarrollado su actividad normal en entrenamiento y partido, y los registros han sido recogidos y analizados posteriormente.

Criterios de inclusión y exclusión comunes

De los registros obtenidos en entrenamiento, se han considerado exclusivamente las sesiones de campo, descartando las sesiones de entrenamiento realizadas en gimnasio y las sesiones puramente tácticas (p.ej., acciones a balón parado). Sólo se han incluido en los análisis los microciclos[11] de entrenamiento correspondientes al periodo competitivo que contaban con un partido semanal y con un mínimo de 4 sesiones de entrenamiento previas al partido. Por tanto, los datos correspondientes a pretemporada, Navidad y los microciclos con dos partidos semanales o en los que no había partido fueron excluidos del análisis para evitar una mayor variabilidad en los resultados. Además, también se excluyeron los registros de los jugadores que no realizaron la sesión de entrenamiento completa y los jugadores que participaron en menos de 80 minutos durante el partido. Finalmente, sólo se consideraron los registros de los jugadores de campo, excluyendo los registros correspondientes a los porteros.

[10] Este artículo es una opinión de expertos y ha sido publicado como editorial. No guarda relación con la muestra analizada en los restantes artículos.
[11] El microciclo es referido a un periodo de tiempo correspondiente a una semana.

En la Tabla 4 se resume la información metodológica específica más relevante de cada uno de los artículos que componen la presente Tesis Doctoral.

Tabla 4. Resumen de la metodología utilizada en los diferentes estudios que componen esta Tesis Doctoral.

Estudio	Diseño	Muestra	Variables	Métodos
A new approach for TL quantification.	Comparativo e inferencial	30 futbolistas de un equipo de Primera División española	Variables de TM y metabólicas recogidas en entrenamiento con GPS: ACCs, DECs, TotalD, LSRD, MSRD, HSRD, VHSRD, SPD, MP, MW, MPev, PowerE, EqD. Además, se consideraron los factores contextuales periodo de la temporada y calidad del equipo rival.	Se realizó un análisis de la TL de los futbolistas diferenciando por posición de juego y según los diferentes días del microciclo semanal. T-Test, ANOVA, Pearson, *d*-Cohen, η^2, R^2 y Wald t-test.
The effect of coach change on physical performance	Transversal, comparativo e inferencial	Futbolistas de 3 equipos profesionales españoles compitiendo en las categorías de Primera, Segunda y Segunda División B.	Variables de TM y metabólicas cuantificadas con GPS en entrenamiento y partido: MP, MPEv, PowerE, Pmax, EDI, ACCs, DECs, Vmax, TotalD, WalkD, LSRD, MSRS, HSRD, VHSRD, SPD.	Se realizó un análisis de las respuestas físicas realizadas por los futbolistas en cada uno de los equipos en entrenamiento y en partido durante las 4 semanas previas y posteriores a la destitución del entrenador. Wilcoxon test, *d*-Cohen.
The effect of training load and contextual factors on match responses	Comparativo e inferencial	30 futbolistas de un equipo de Primera División española y 26 de un equipo de Segunda División española.	Parámetros de TM recogidos mediante GPS en entrenamiento y partido: TD, HIRD y SPD (considerando sólo >24 $km \cdot h^{-1}$). Además, también se consideraron los factores contextuales periodo de la temporada, calidad oponente, posición de juego, división y formación.	Primero, se agruparon todos los registros de TL y ML por jugador y por semana. Posteriormente se analizó la relación entre la TL y la respuesta física mostrada por los jugadores en partido mediante modelos lineales mixtos, considerando los factores contextuales. Correlaciones (*r*), modelos mixtos (lme4), R^2 condicional

The effect of coronavirus on physical performance	Editorial	Futbolistas de élite en todo el mundo.	Parámetros de carga interna y externa: composición corporal, capacidad cardiorrespiratoria, capacidad muscular, actividad de locomoción. Incidencia de lesiones	Se envió por correo electrónico un cuestionario compuesto de 5 preguntas abiertas a cada uno de los expertos que quisieron participar voluntariamente en el estudio, con objeto de reunir la opinión de expertos, discusión y contraste con la literatura actual. (No precisa de pruebas estadísticas)

X. Resultados & Discusión

Estudio 1

A new approach for training-load quantification in elite-level soccer: contextual factors

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A new approach for training-load quantification in elite-level soccer: contextual factors

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ABSTRACT

The aims of this study were to analyse the physical responses of professional soccer players in training considering the contextual factors match location, season period, and quality of opposition; and establish prediction models of physical responses in training taking into account different factors from which there is a significant change in physical performance. Training data was obtained from 30 professional soccer players who belonging to a First Spanish Division team using global positioning technology (*N*=1365 performances). Lower workload was showed on the training week prior to home match, showing large effects in power events, equivalent distance, total distance, walk distance and low-speed running distance. In addition, the quality of opposition also affected the training workload ($p<.05$). All regression-models showed moderate effects, with an adjusted R^2 of .37 for metabolic-work, .34 for total distance covered, .25 for high-speed running distance (18 to 21 $km \cdot h^{-1}$), .29 for very high-speed running distance (21 to 24 $km \cdot h^{-1}$), .22 for sprint running distance (>24 $km \cdot h^{-1}$) and .34 for equivalent distance. The main finding of this study was the great affectation of match location, season period and quality of opposition on the workload performed by players in the training week before the match; and the development of workload prediction-models considering these contextual factors, thus proposing a new and innovative approach to quantify the workload in soccer.

Keywords: Physical responses, GPS, time motion analysis, monitoring, situational variables

INTRODUCTION

Nowadays winning is the most important aspect in high-level soccer [1]. Despite many factors (technical, tactical, physical or physiological, among others) affect the performance of players [2], performance is currently assessed through victory or defeat. It is known that players required a multi-faceted ability that responds to the game needs [3]. In an increasingly demanding sport, where teams compete up to twice a week for a long period, players require a good readiness to withstand the match demands over the season and avoid increasing the risk of injury [4,5]. Therefore, developing an appropriate load periodization and programming is of paramount importance in high-level. Global Positioning Systems (GPS) have been shown to be a valid and reliable tools to monitor the external load of elite soccer players in both training and matches [6–8]. These devices provide detailed information relative to the locomotion activity performed by players such as time-motion or metabolic metrics. The analysis of locomotion activity based on speed-running (e.g., high-intensity distance, number of accelerations or sprint distance) is the most used method to monitor external load in soccer [9,10]. However, an increasing number of authors currently support the metabolic approach based on the energy cost (e.g. metabolic power, equivalent distance or metabolic power events) as more accurate method for workload monitoring due to it considers the energy cost associated with accelerative and decelerative phases during the soccer-specific activities [6,11].

High-level soccer has evolved in recent years requiring better physical, technical and tactical preparation of players to withstand the increased competition demands [4,5]. Therefore, practitioners must take into account a wide myriad of factors that may affect the physical performance of players in order to improve the training program and achieve a better readiness for the match. In this sense, many studies have shown the contextual factors such as match location [12,13], quality of opposition [12,14,15] or season period [13,14] greatly affect the players' physical responses in match and, consequently, in match outcome. These authors found that home teams covered longer total distance and the best teams showed higher ball possession. In addition, regardless of the quality of opposition and the match location, an increased total distance and high-intensity distance were covered in the last period of season. Finally, different physical responses were found by playing position [16–19].

However, most of authors have analysed the effect of contextual factors on players' physical responses in competition [20–24], and only few authors have analysed how contextual factors affect the physical performance in training sessions [25,26]. These authors found a significant affectation of contextual factors on the workload applied on the training week after the match and consider that taking into account the contextual factors on the training week just before the match would of great practical application for practitioners to make decisions on the training load (TL) programming.

Knowing that away matches or playing against a top-quality team the physical responses developed by players in match are higher than when the match is at home [12,13] or playing against lower quality team [12,14,15], the authors hypothesized that when the match is against top-quality team or when playing away the physical responses performed by players on the training days (TDs) just before the match will be also higher in order to simulate the upcoming-match demands. On the other hand, contrary to other authors who found higher physical responses on the last period of season [13,14], the authors also believe that TL will be higher on the initial period of competitive season because players are still 'fresh' and might continue his initial physical preparation from preseason. Therefore, there is a double object of study; (1) to analyse the effect of match location, season period and quality of opposition on the physical responses of professional soccer players in the training week prior to match; and (2) to establish predictive models of several physical metrics in training considering the effect of contextual factors.

MATERIAL & METHODS

Participants and sample

Training data was collected from thirty male professional soccer players (22.8±0.8 yr; 177.8±6.9 cm; 73.3±5.7 kg) belonging to a Spanish First Division team during the 2015-2016 season (N=1365 cases). Only the data corresponding to team training sessions performed on the field during the competitive period was used. The records obtained during preseason and non-competition period (corresponding to Christmas), in addition to purely tactical and strength sessions realized at gym have also been excluded to avoid variability in the training records. The Competitive Period began in microcycle

8, corresponding to the second match-week. Thus, a total of 33 training weeks were include.

Players were classified into five playing positions [16,17,27]: Central Defender (CD), External Defender (ED), Central Midfielder (CM), Wide Midfielder (WM) and Forward (FO). Goalkeepers and players who did not complete the entire training session were also excluded from the analysis. Training sessions were divided according to the TD relative to the match day (MD): 4 days before the match (MD-4), 3 days before the match (MD-3), 2 days before the match (MD-2) and 1 day before the match (MD-1). Training sessions developed before MD-4 are usually orientated to recovery [28,29] and were not considered for analysis as do not present any specific and representative content by position. Punctual microcycles with two weekly matches and exclusively tactical training sessions were discarded from the study.

The Club and players were informed about the aim of this study, and consent was obtained by both. This study was approved by the University of Granada Ethics Committee (Number 471/CEIH/2018). It complied with the ethical standards of the Journal [30] and followed the guidelines of the Declaration of Helsinki (2013).

Data collection procedures and variables analysed

Global Positioning System devices (GPS) of 18.18Hz (GPEXE Pro®, GPEXE, Udine, Italy) were used to collect data for this study for all training sessions. The number of satellites during the training and matches was 8±1.

Time-motion parameters and metabolic variables were analysed. The time-motion parameters are as follows: acceleration events (ACC), considered as the number of speed increments equal to or greater than 2 $m·s^{-2}$ during an interval time equal to or less than 0.5 seconds; deceleration events (DEC), considered as the number of braking or speed decrements equal to or less than -2 $m·s^{-2}$ during an interval time equal to or less than 0.5 seconds; total distance covered during the match (TotalD); low-speed running distance (LSRD), i.e., the distance covered at speeds less than 14 $km·h^{-1}$; medium-speed running distance (MSRD), from 14 to 18 $km·h^{-1}$; high-speed running distance (HSRD), from 18 to 21 $km·h^{-1}$; very-high-speed running distance (VHSRD), from 21 to 24 $km·h^{-}$

^{1}; and sprint running distance (SPD), higher than 24 km·h^{-1}. All evaluated distances were recorded in meters. The variables belonging to the metabolic approach analysed in this study are as follows: average metabolic power (MP); metabolic work (MW, in kJ), which was calculated as the product of average metabolic power and training duration in seconds; mean metabolic power of high-intensity actions (MPev, on W·kg^{-1}), which considers the actions with intensities equal to or greater than 20 W·kg^{-1}; number of high-intensity events (PowerE); and the equivalent distance (EqD, in meters), based on the distance that the player would have covered at a steady pace, using the total energy consumed over the match [11,31].

Relative to contextual factors, training and match data were classified according to the season period; from August to November (Start), December to February (Middle) and March to May (Final) [5,13,14]; and considering the quality of opposition; differentiating the teams in three levels according their League ranking at the end of the previous match-week [25]: 'Top-teams' (1st to 6th), 'Medium-teams' (7st to 14th) and 'Weak-teams' (15st to 20th). Only the TDs prior-to a League match have been included, excluding the TDs before a Cup-match or the weeks without competition.

Statistical Analysis

Microsoft Excel 2019 (Microsoft Corp, Redmond, Washington, USA), SPSS (version 25.0; SPSS Inc., Chicago) and R Studio (version 3.6.1; R Core Team, 2019) were used for data processing and statistical analyses. For all analyses, the level of significance was set at $p \leq .05$ and the results have been described as means ± SD. First, the Kolmogorov-Smirnov test was performed to know if dependent variables had a normalized distribution. The results showed that these variables did not present a normalized distribution. However, due to the large sample size of each group, the central limit theorem was applied to provide normally distributed sample means [32]. Therefore, the parametric analyses were performed in this study. The relationships between dependent variables and contextual factors were determined using multiple bivariate correlations, represented by Pearson's coefficient. The magnitude of the correlation was interpreted as follows: <0.1, trivial; from 0.1 to 0.3, small; from 0.3 to 0.5, moderate; from 0.5 to 0.7, large; from 0.7 to 0.9, very large; and from 0.9 to 1.0, almost perfect [33]. To compare the TL between groups considering the match location (home or away), independent-samples T-tests were performed. ANOVA and Bonferroni post hoc tests, with quality of opposition (weak, medium or top teams) as factor, were conducted in order to know the differences among TL' variables between quality of teams and season period. Subsequently, Cohen's *d* (for T-test analyses) and Eta-squared (η^2, for ANOVA test) were used to quantify the effect size (ES) for interpreting the differences that were found between groups [34,35]. The threshold values for Cohen's *d* are: <0.2 for trivial effect, 0.2 to 0.5 for small effect, 0.5 to 0.8 for moderate effect, and >0.8, for large effect [34]. The values of ES for η^2 are 0.02 for small effects, 0.15 for moderate effects and 0.35 for large effects. Finally, in order to examine the effect of the different contextual factors on the TL, different regression models were fit for the different dependent variables. These variables were MW, TotalD, HSRD, VHSRD, SPD, and EqD, resulting in six regression models. The independent variables used were the same for all models, i.e., season period, number of days before the MD, the position of the respective player, location of the upcoming match and the quality of opposition. All independent variables were coded as categorical variables. The fit and overall significance of the respective models were estimated using the determination coefficient R-squared (R^2) and the significance of the respective predictors was checked using Wald t-tests.

RESULTS

Table 1 shows the relationship between contextual factors and TL parameters determined by Pearson's coefficient test. Several significant correlations ($p.\leq 05$ and $p.\leq 01$) were found between the physical responses and the contextual factors, being the match location, which presented a higher number of correlations. The correlations showed trivial and small effects.

*Tabla 5.*Estudio 1 – [Table 1. Pearson's coefficient test of physical responses and contextual factors].

Variable	MP	MPev	PowerE	ACC	DEC	EqD	TotalD	WalkD	LSRD	MSRD	HSRD	VHSRD	SPD
SeasonP	-.078**	-.050	-.007	.057*	.041	-.033	-.043	-.022	-.004	-.064*	-.163**	-.196**	-.110**
Location	.099**	.068**	.145**	.143**	.113**	.135**	.132**	.173**	.155**	-.011	.110**	.135**	.002
RQ	-.021	.067**	.055*	.048	.084**	.051*	.048	.046	.048	.019	.013	.017	.103**

*($p\leq.05$), **($p\leq.01$); SeasonP, season period; MO, Match outcome; RQ, rival-team quality; MP, averaged Metabolic Power on $W\cdot kg^{-1}$; MPev, mean metabolic power of high-intensity actions on $W\cdot kg^{-1}$; PowerE, number of high-intensity events ($\geq$20 $W\cdot kg^{-1}$); ACC, acceleration events; DEC, deceleration events; EqD, Equivalent Distance on meters; TotalD, total distance covered on meters; WalkD, total walking distance covered (0 to 7 $km\cdot h^{-1}$); LSRD, low-speed running distance (<14 $km\cdot h^{-1}$); MSRD, medium-speed running distance (14 to 18 $km\cdot h^{-1}$); HSRD, high-speed running distance (18 to 21 $km\cdot h^{-1}$); VHSRD, very high-speed running distance (21 to 24 $km\cdot h^{-1}$); SPD (>24 $km\cdot h^{-1}$)

Match location

The independent-samples T-test concerning to the match location showed higher workload values on training-weeks when the team played an away-match compared to training-weeks before a home-match. Except for MSRD and SPD, all the parameters analysed were significant for $p<.01$ (Table 2). PowerE, EqD, TotalD, WalkD and LSRD showed large effects (d=.47, .52, .50, .60 and .58, respectively).

Tabla 6. Estudio 1 – [Table 2. Descriptive data (mean ± SD), Cohen's d and effect size (ES) interpretation of variables with significant variance between them, considering the match location (home or away) of the upcoming match].

Variable	Home (N=722)	Away (N=643)	*p*	*d*	*ES*
MP	6.4±1.1	6.7±1.1	***	.27	*Mod*
MPev	28.2±2.0	28.6±1.7	**	.17	*Small*
PowerE	69.1±24.4	81.3±27.6	***	.47	*Large*
ACC	37.7±15.6	43.6±15.9	***	.37	*Mod*
DEC	35.8±15.5	41.4±16.2	***	.35	*Mod*
EqD	4515.6±1303.7	5212.7±1389.2	***	.52	*Large*
TotalD	4025.2±1188.2	4633.3±1242.8	***	.50	*Large*
WalkD	2037.9±547.2	2370.0±569.1	***	.60	*Large*
LSRD	3275.4±941.1	3837.3±1006.2	***	.58	*Large*
HSRD	152.4±126.9	185.2±102.3	***	.28	*Mod*
VHSRD	69.0±59.2	93.1±80.7	***	.34	*Mod*

($p\leq.05$) *; ($p\leq.01$) **; ($p\leq.001$) ***. MP, averaged Metabolic Power on $W\cdot kg^{-1}$; MPev, mean metabolic power of high-intensity actions on $W\cdot kg^{-1}$; PowerE, number of high-intensity events ($\geq$20 $W\cdot kg^{-1}$); ACC, acceleration events; DEC, deceleration events; EqD, Equivalent Distance on meters; TotalD, total distance covered on meters; WalkD, total walking distance covered (0 to 7 $km\cdot h^{-1}$); LSRD, low-speed running distance (<14 $km\cdot h^{-1}$); HSRD, high-speed running distance (18 to 21 $km\cdot h^{-1}$); VHSRD, very high-speed running distance (21 to 24 $km\cdot h^{-1}$).

Quality of opposition

ANOVA with Bonferroni's post hoc tests were carried out to compare the TL between top-, medium-, and weak quality teams: in MPev, the medium-quality teams showed different values than weak ($p<.01$) and top teams ($p<.001$), and weak teams differed from top teams ($p<.05$); in the variable DEC, weak teams differed from medium ($p<.01$) and top teams ($p<.001$); in EqD, the weak teams showed variability compared to medium ($p<.001$) and top teams ($p<.001$); in TotalD, weak teams differed from medium ($p<.05$) and top teams ($p<.01$); in LSRD, weak differed again from medium ($p<.01$) and top teams ($p<.001$); for the metric MSRD, medium differed from weak ($p<.001$) and top teams ($p<.05$); for VHSRD, the workload applied by medium teams was different than weak (*p*<.001) and top teams (*p*<.001); and finally in SPD, top teams differed from weak (*p*<.001) and medium teams (*p*<.001).

Season period

The regression model coefficients showed a decrease in all training load variables from the start to the middle period of season and a further decrease from the middle to the end of the season. In all regression models of physical metrics, both the coefficients for start- and middle period showed significant results in the Wald t-tests (*p*<.001), corroborating the reliability of the estimations.

Prediction Models

The equations for the six models are shown in Table 3. All models showed overall significant effects (*p*<.001). The models for MW yielded an adjusted R^2 value of .37; TotalD=.34; HSRD=.25; VHSRD=.29; SPD=.22 and EqD=.34. The predictions made by the model, i.e. the mean values of the respective load variables depending on the different independent variables are shown in Figure 1.

Tabla 7. Estudio 1 – [Table 3. Coefficients for the models of the different load parameters (columns) and the respective independent variables (rows). SeasonP, season period; MD, match day; Pos, playing position; Loc, match location; RQ, rival-team quality; Med, medium].

	Equation
Model 1	MW = 17.77 + (x * Season) + (y * MD) + (z * Pos) + (a * Loc) + (b * RQ)
	x: SeasonP: Final: 1; SeasonP: Middle = 1.42; SeasonP: Start = 1.13; y: MD-1= 1; MD-2 = 2.31; MD-3 = 5.88; MD-4 = 8.15 z: CD = 1; CM = 1.13; ED = 0.19; FO = 0.71; WM = 0.47 a: Home = − 2.55; Away = 1 b: Low teams = 1; Med teams = − 0.16; Top teams = − 0.78
Model 2	MW = 3220.7 + (x * Season) + (y * MD) + (z * Pos) + (a * Loc) + (b * RQ)
	x: SeasonP: Final: 1; SeasonP: Middle = 265.9; SeasonP: Start = 513.1; y: MD-1= 1; MD-2 = 307.8; MD-3 = 1054.3; MD-4 = 1597.8 z: CD = 1; CM = 251.13; ED = 6.74; FO = 86.01; WM = 91.4 a: Home = − 282.65; Away = 1 b: Low teams = 1; Med teams = 18.39; Top teams = 108.84
Model 3	MW = 63.19 + (x * Season) + (y * MD) + (z * Pos) + (a * Loc) + (b * RQ)
	x: SeasonP: Final: 1; SeasonP: Middle = 55.03; SeasonP: Start = 69.84; y: MD-1= 1; MD-2 = − 0.45; MD-3 = 67.89; MD-4 = 97.28 z: CD = 1; CM = 28.48; ED = 30.23; FO = 65.72; WM = 48.9 a: Home = − 2.31; Away = 1 b: Low teams = 1; Med teams = − 24.23; Top teams = − 18.17
Model 4	MW = 35.79 + (x * Season) + (y * MD) + (z * Pos) + (a * Loc) + (b * RQ)
	x: SeasonP: Final: 1; SeasonP: Middle = 28.96; SeasonP: Start = 45.93; y: MD-1= 1; MD-2 = − 0.37; MD-3 = 45.83; MD-4 = 28.4 z: CD = 1; CM = − 1.97; ED = 31.13; FO = 35.58; WM = 34.82 a: Home = − 9.41; Away = 1 b: Low teams = 1; Med teams = − 27.84; Top teams = − 9.81
Model 5	MW = − 8.04 + (x * Season) + (y * MD) + (z * Pos) + (a * Loc) + (b * RQ)
	x: SeasonP: Final: 1; SeasonP: Middle = 1.42; SeasonP: Start = 1.13; y: MD-1= 1; MD-2 = − 0.61; MD-3 = 26.82; MD-4 = 16.41 z: CD = 1; CM = − 8.82; ED = 31.29; FO = 24.29; WM = 29.2 a: Home = 7.05; Away = 1 b: Low teams = 1; Med teams = − 6.07; Top teams = 17.32
Model 6	MW = 3655.08 + (x * Season) + (y * MD) + (z * Pos) + (a * Loc) + (b * RQ)
	x: SeasonP: Final: 1; SeasonP: Middle = 283.04; SeasonP: Start = 502.99; y: MD-1= 1; MD-2 = 348.24; MD-3 = 1209.94; MD-4 = 1779.58 z: CD = 1; CM = 256.68; ED = 28.87; FO = 161.75; WM = 114.04 a: Home = − 341.16; Away = 1 b: Low teams = 1; Med teams = 1.32; Top teams = 127.65

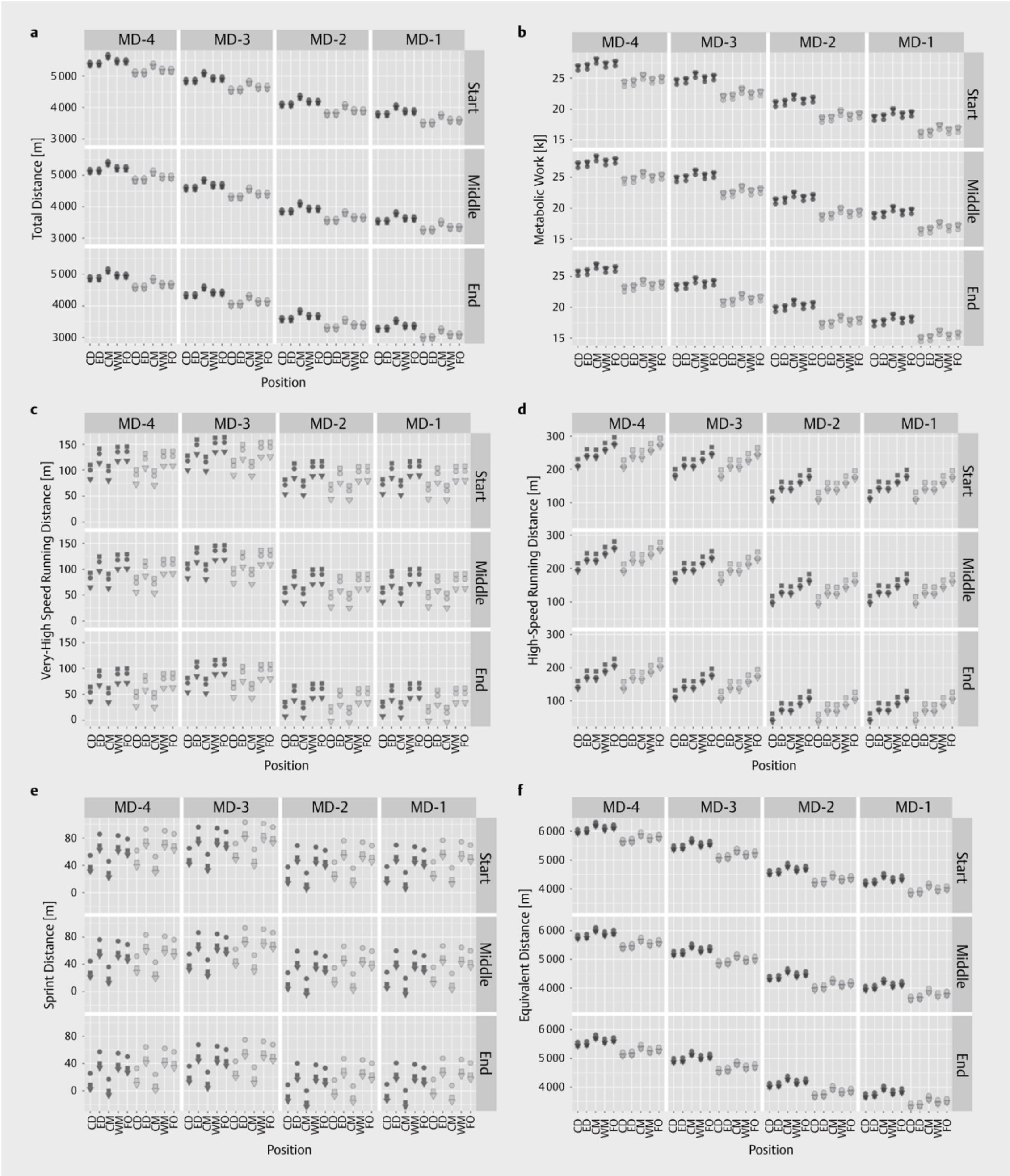

Figura 3. Estudio 1 – [Figure 1: Predictions of regression models for Total Distance (a), metabolic work (b), high-speed running distance (c), very high-speed running distance (d), sprint running distance (e) and equivalent distance (f); depending on the five independent variables. The analysed metrics are shown on Y-axis, and playing position on X-axis. The factors season period and number of days before the match are shown by splitting the data into grids. Besides, the colour of points indicates the location of the upcoming match, dark colour for away match and light colour for home matches; and the shape of points indicates the quality of the opponent; squares for bottom teams, triangles for medium teams and circles for top teams].

DISCUSSION

The main goal of this study was to analyse and compare the TL in elite soccer players considering different contextual factors and develop prediction models of physical metrics from the different factors considered. The results showed differences on the TL performed by players among microcycles depending on the quality of opposition and the location of the upcoming match. However, the main finding of this study was the significant effects found in all regression-models, thus proposing a new and innovative approach for training load quantification and planning, taking into account the different contextual factors.

It is well known that contextual factors such as location or quality of opposition highly affect the physical responses of players in match [20,26,36]. Indeed, Lago-Peñas [20] concluded that these situational variables should be considered for the post-match analysis of physical performance. However, there is scarce research analysing how the contextual factors affect on physical performance in training. The results of the present study showed significant correlations between contextual factors and the different physical responses in training, and the match location was the factor with the greatest influence on physical responses. In this sense, many authors agree that home teams cover higher low-speed distance in competition [12,13]. However, these authors did not find significant differences at maximum or sub-maximum intensities. On the other hand, there are authors that analysed how the match location affects on the workload performed by players in the training-week. Rago et al. [26] found lower number of accelerations and decelerations events on the week after playing away, and Brito et al. [25] showed higher TL after playing away. The present study found several variances among metrics, showing higher values in all physical responses on the training-week when the upcoming match took place away compared to playing at home. Conversely, Brito et al. [25] found higher RPE (rate of perception effort) when preparing for a home match. However, it should be noted that the present study analysed the effect of match location on the locomotion activity in the training week just before the match, whereas Rago et al. [26] analysed the effect over the following week and Brito et al. [25] considered the internal load (RPE). Relative to season period, some authors have suggest a monotony in training methods in professional soccer due to the similar TL found over the season [27]. Other studies have shown the highest total distance and high-intensity distance in the final period [13,14]. Conversely, these results showed higher physical responses at the beginning of season compared to the rest of the season, whereas load also tended to be a little higher in the middle period compared to the end of the season. It may be due to players were exhausted at the end of season, so the TL was adjusted either consciously by coaches or unconsciously by players. Therefore, there is controversy in the research regarding to season period.

The quality of opposition is one of the most determinant factors on the physical performance developed by players [15,20,37]. In match, playing against the best teams requires a greater physical effort, and these efforts are usually made without the ball in the attempt to regain possession. Thus, it may be adequate to consider the quality of next rival for programming the weekly TL in order to achieve a more specific preparation and peak performance on match. Although the authors do not know if the technical staff considered this factor for TL programming, this study found variability on the TL depending on whether the team played against top, medium or weak teams. In line with Brito et al. [25], the results showed higher TL during the training-week when the team played against top-teams. Contrary to this study, Rago et al. [26] found higher TotalD, ACC and DEC on the week before the match when played against weak teams. Therefore, this study suggests that the quality of opposition should be considered for TL periodization due to the effect on physical performance. On the other hand, it might also be interesting to take into account the quality of the opponent to carry out a tapering strategy for future matches [17]. For instance, if the analysed team is on the bottom of ranking-table and the next match is against one of the best teams, but the 3 following matches are against direct rivals (i.e., similar ranking), it may be more adequate to periodize the TL in order to peak performance on these matches.

As discussed above, contextual factors also affect the players' physical performance during the training-week before the match. However, for the knowledge of authors, it is unknown how practitioners could take into account the specific influence of these factors on the workload planning during the training sessions before the match. With the aim of considering the effect of contextual factors on TL quantification, prediction models of running-distances and MW metrics have been developed. The regression analyses showed similar trends for most of load parameters, but some differences were found. The largest TL changes were induced by training-day, i.e. the number of days between training-session and the upcoming match. However, no large differences were showed between MD-2 and MD-1. In the same line, other authors have found a greater load reduction on MD-2 and MD-1 compared to other TDs [17]. For these authors, it may be due to the tapering strategy of microcycle and the specific physical contents developed, focused on the reduction of TL by the proximity of match. Besides, these authors also considered necessary to contextualize each TD to different goals: MD-2 was oriented to train technical skills and tactics whilst MD-1 was oriented to low-intensity activation exercises and set pieces. Interestingly, in this study the metrics TotalD, EqD, MW and HSRD were reduced linearly with every training session, while VHSRD and SPD were first increased from MD-4 to MD-3 to be drastically reduced towards MD-2 and to be slightly increased again to MD-1, giving insight into an important aspect of periodization. While TotalD and high-speed running distances, as well as metabolic parameters, may all be used to quantify load characteristics, they may not reflect the same 'type' of load. Especially VHSRD and SPD did not follow the same trends as the remaining variables. Therefore, VHSRD and SPD might be intensity-related metrics, whereas the others (TotalD, EqD, MW and HSRD) may be volume-related.

Although it has been proposed a new perspective for load analysis considering the contextual factors, this study presents certain limitations. The results obtained belong to a single team. Moreover, technical-tactical factors such as playing style have not been considered in the analysis. On the other hand, it is likely the factor quality of opposition may affect differently if the analysed team play against a team is under- or over- ranked. For instance, the analysed team ranking bottom positions and playing against top-tier team, or if both teams are in the same tier. In addition, it is likely different playing against top- or bottom-tier team if the referred team is ranked at the top, medium or bottom table. However, to build the prediction models the authors did not considered this approach because it wanted to know the effect of the quality of opposition, and not according the difference in the ranking between teams. So, authors wanted to prevent 'similar results' when playing against equal-tier teams but at the top or bottom. In addition, this paper considers the quality of opposition in the same way that others authors [20,25,26]. Finally, only the TL has been analysed. In this sense, future lines of research should focus on analysing the TL together with the match demands, collecting a greater number of teams, considering the technical-tactical elements, and analysing the physical performance fluctuations when playing against similar, lower or higher ranking-tier.

CONCLUSIONS

Two important conclusions can be drawn from this study. First, insights on the periodization of a high-level soccer team depending of contextual factors can be made. Second, two different categories of TL parameters may be identified; on the one hand, TotalD, HSRD, EqD, and MW might be termed volume-related load parameters; on the other hand, SPD and VHSRD, which could be termed intensity-related load parameters. Practitioners must take into account this distinction when reporting about team's workload. Other interesting findings are that situational variables as match location or the quality of opposition alter the TL developed by players. The players showed higher TL within the training-week when the upcoming match was away and against a top opponent. However, consideration should be given to possible tapering strategies by team. It does not know if it might either be that there is a conscious reason for this planning or that an unconscious and unwanted alteration in TL was identified. Either way, further studies should try to identify why contextual factors may alter the TL and how the training load interacts with training contents.

PRACTICAL APPLICATIONS

It is known that contextual factors highly outcome on the physical performance developed by players. However, most studies have only analysed the match load. This study proposes a new and innovative approach for TL quantification through TL' prediction-models considering different contextual factors which might be useful into the soccer practice. These equations might be very useful for coaches to improve the TL periodization and programming 'predicting' the TL that players should develop on the different TDs by playing position considering the effect of the season period, match location and quality of opposition. Therefore, these models predict the recommended TL in order to achieve the best readiness considering the upcoming 'match scenario'. Furthermore, for the upcoming 'match scenario' and then coaches and staff can program the load based on these recommendations. In addition, it is recommended to discriminate between volume- and intensity- related variables into the load periodization in soccer.

REFERENCES

1 *Kattuman P, Loch C, Kurchian C.* Management succession and success in a professional soccer team. *PLoS One* 2019;14:1–20. doi:10.1371/journal.pone.0212634

2 *Hughes MD, Bartlett RM.* The use of performance indicators in performance analysis. *J Sports Sci* 2002;20:739–54. doi:10.1080/026404102320675602

3 *Paul DJ, Bradley PS, Nassis GP.* Factors Affecting Match Running Performance of Elite Soccer Players: Shedding Some Light on the Complexity. *Int J Sports Physiol Perform* 2015;10:516–9. doi:10.1123/ijspp.2015-0029

4 *Bradley PS, Archer DT, Hogg B, et al.* Tier-specific evolution of match performance characteristics in the English Premier League: it's getting tougher at the top. *J Sports Sci* 2016;34:980–7. doi:10.1080/02640414.2015.1082614

5 *Dellal A, Lago-Peñas C, Rey E, et al.* The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *Br J Sports Med* 2015;49:390–4. doi:10.1136/bjsports-2012-091290

6 *Di Prampero PE, Osgnach C.* Metabolic Power in Team Sports - Part 1: An Update. *Int J Sports Med* 2018;39:581–7. doi:10.1055/a-0592-7660

7 *Ehrmann FE, Duncan CS, Sindhusake D, et al.* GPS and Injury Prevention in Professional Soccer. *J strength Cond Res* 2016;30:360–7. doi:10.1519/JSC.0000000000001093

8 *Malone JJ, Lovell R, Varley MC, et al.* Unpacking the Black Box: Applications and Considerations for Using GPS Devices in Sport. *Int J Sports Physiol Perform* 2017;12:S2-18-S2-26. doi:10.1123/ijspp.2016-0236

9 *Cardinale M, Varley MC.* Wearable Training-Monitoring Technology: Applications, Challenges, and Opportunities. *Int J Sports Physiol Perform* 2017;12:S255–62. doi:10.1123/ijspp.2016-0423

10 *Nassis GP, Gabbett TJ.* Is workload associated with injuries and performance in elite football? A call for action. *Br J Sports Med* 2017;51:486–7.

doi:10.1136/bjsports-2016-095988

11 *Osgnach C, Poser S, Bernardini R, et al.* Energy cost and metabolic power in elite soccer: A new match analysis approach. *Med Sci Sports Exerc* 2010;42:170–8. doi:10.1249/MSS.0b013e3181ae5cfd

12 *Lago-Peñas C, Rey E, Lago-Ballesteros J, et al.* The influence of a congested calendar on physical performance in elite soccer. *J strength Cond Res* 2011;25:2111–7. doi:10.1519/JSC.0b013e3181eccdd2

13 *Mohr M, Krustrup P, Bangsbo J.* Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 2003;21:519–28. doi:10.1080/0264041031000071182

14 *Rampinini E, Coutts AJ, Castagna C, et al.* Variation in Top Level Soccer Match Performance. *Int J Sports Med* 2007;28:1018–24. doi:10.1055/s-2007-965158

15 *Castellano J, Blanco-Villaseñor A, Álvarez D.* Contextual Variables and Time-Motion Analysis in Soccer. *Int J Sports Med* 2011;32:415–21. doi:10.1055/s-0031-1271771

16 *Martín-López Á, Mendes RS, Castillo-Rodríguez A.* Internal and External Loads in Training Week Before the Competition in U19 High-Level Soccer Players. *J strength Cond Res* 2018;00:1–7. doi:10.1519/JSC.0000000000002975

17 *Martín-García A, Gómez Díaz A, Bradley PS, et al.* Quantification of a professional football team's external load using a microcycle structure. *J Strength Cond Res* 2018;32:3511–8. doi:10.1519/jsc.0000000000002816

18 *Owen AL, Djaoui L, Newton M, et al.* A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer. *Sci Med Footb* 2017;3938:1–6. doi:10.1080/24733938.2017.1334958

19 *Malone S, Owen AL, Mendes B, et al.* High-speed running and sprinting as an injury risk factor in soccer: Can well-developed physical qualities reduce the risk? *J Sci Med Sport* 2017;21:257–62. doi:10.1016/j.jsams.2017.05.016

20 *Lago-Peñas C.* The role of situational variables in analysing physical performance in soccer. *J Hum Kinet* 2012;35:89–95. doi:10.2478/v10078-012-0082-9

21 *Lago-Peñas C.* The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *J Sports Sci* 2009;27:1463–9. doi:10.1080/02640410903131681

22 *Chmura P, Konefał M, Chmura J, et al.* Match outcome and running performance in different intensity ranges among elite soccer players. *Biol Sport* 2018;35:197–203. doi:10.5114/biolsport.2018.74196

23 *Lago-Peñas C, Lago-Ballesteros J, Dellal A, et al.* Game-Related Statistics that Discriminated Winning, Drawing and Losing Teams from the Spanish Soccer League. *J Sports Sci Med* 2010;9:288–93.

24 *Castellano J, Casamichana D, Lago C.* The Use of Match Statistics that Discriminate Between Successful and Unsuccessful Soccer Teams. *J Hum Kinet* 2012;31:139–47. doi:10.2478/v10078-012-0015-7

25 *Brito J, Hertzog M, Nassis GP.* Do Match-Related Contextual Variables Influence Training Load in Highly Trained Soccer Players? *J Strength Cond Res* 2016;30:393–9. doi:10.1519/JSC.0000000000001113

26 *Rago V, Rebelo A, Krustrup P, et al.* Contextual Variables and Training Load Throughout a Competitive Period in a Top-Level Male Soccer Team. *J Strength Cond Res* 2019;:1. doi:10.1519/jsc.0000000000003258

27 *Malone J, Di Michele R, Morgans R, et al.* Seasonal training-load quantification in elite English premier league soccer players. *Int J Sports Physiol Perform* 2015;10:489–97. doi:10.1123/ijspp.2014-0352

28 *Owen AL, Dunlop G, Rouissi M, et al.* Analysis of positional training loads (ratings of perceived exertion) during various-sided games in European professional soccer players. *Int J Sport Sci Coach* 2016;11:374–81. doi:10.1177/1747954116644064

29 *Owen AL, Lago-Peñas C, Gómez MÁ, et al.* Analysis of a training mesocycle and positional quantification in elite European soccer players. *Int J Sport Sci Coach* 2017;12:665–76. doi:10.1177/1747954117727851

30 *Harriss DJ, Macsween A, Atkinson G.* Ethical Standards in Sport and Exercise Science Research: 2020 Update. Int J Sports Med 2019; 40: 813-817.

31 *Polglaze T, Hoppe MW.* Metabolic Power: A Step in the Right Direction for Team Sports. *Int J Sports Physiol Perform* 2019;:1–5. doi:10.1123/ijspp.2018-0661

32 *Altman DG. Practical statistics for medical research.* CRC press: 1990.

33 *Hopkins WG, Marshall SW, Batterham AM, et al.* Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 2009;41:3–

12. doi:10.1249/MSS.0b013e31818cb278

34 *Cohen J.* Statistical power analysis for the behavioral sciences. Routledge: 1988.

35 *Coe R, Merino C.* Magnitud del efecto: Una guía para investigadores y usuarios. *Rev Psicol a – PUCP* 2003;21:147–77.

36 *Lago C, Martín R.* Determinants of possession of the ball in soccer. *J Sports Sci* 2007;25:969–74. doi:10.1080/02640410600944626

37 Di Salvo V, Gregson W, Atkinson G, *et al.* Analysis of High Intensity Activity in Premier League Soccer. *Int J Sports Med* 2009;30:205–12. doi:10.1055/s-0028-1105950

Estudio 2

How does the Mid-season Coach Change affect Physical Performance on Top Soccer Players?

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How does the Mid-season Coach Change affect Physical Performance on Top Soccer Players?

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Abstract

The aim of this study was to analyze the locomotion and metabolic responses of professional players in the top three competitive standards of Spanish soccer (First, Second and Second 'B' division) during the four weeks before and after dismissal the coach. Training and match load data were analyzed separately (n=1189 events) by coach (dismissed coach and the new coach) and Wilcoxon-test was performed to compare data between coaches. In training, players covered longer distance in all speed ranges >14 $km \cdot h^{-1}$ with the coach dismissed; medium (14-18 $km \cdot h^{-1}$), high (18-21 $km \cdot h^{-1}$), very-high (21-24 $km \cdot h^{-1}$) and sprint running distance (>24 $km \cdot h^{-1}$) (d=0.53, 0.46, 0.58 and 0.54; respectively) on first division; and equivalent distance index and accelerations events (d=0.63 and 0.50; respectively) on second division. Lower differences were found in matches, in which the dismissed coach showed higher equivalent distance index, accelerations and decelerations events (d=0.69, 0.68 and 0.61; respectively) compared to the new coach in the second division. Therefore, the players covered longer high-intensity distance with the dismissed coach than the new coach in training, whilst a similar performance was found in the competition. These results suggest that the coach turnover at mid-season did no increase the players' physical performance either in training or in competition.

Keywords: Football; metabolic responses; physical responses; GPS; dismissal coach.

Introduction

Soccer is one of the most popular and influential sports in the world, with an estimate of 270 millions people actively involved worldwide [1]. Professional soccer involves a strong economic activity and can be very lucrative. However, high-level competition puts a lot of pressure on players and coaches, caused by several reasons such as poor outcomes, unfulfilled expectations, spectators' complaints or a negative atmosphere with media, among others [2]. It is well known that the most important thing in high-level soccer is to win [2], so coaches and players are usually evaluated by the match score [3,4]. Accordingly, it is common practice to change the coach after a long period of bad results in the attempt to find the solution to turn over the negative streak [5–7]. Although this topic has been studied for many years, it is still unclear whether the change of coach affects teams' performance [5–7]. Kesner & Sebora [8] argued the three sociology succession theories that were introduced by Gamson & Scotch [9] for baseball have dominated successive research in all sports. First, the common-sense theory acknowledges the positive stimulus of coach turnover after suffering a negative streak of results to break that sequence, known as a 'bounce effect'. Second, the vicious-circle theory assumes that change the coach elicits a destabilization into the internal structure of the team and staffing levels, and hence performance decreases. The third explication, the ritual scapegoating theory, underpins that the coach's dismission has no impact on the team's performance and only serves to placate the frustration of stakeholders. There is controversy in the literature regarding this topic; many authors have concluded that the coach turnover was a positive encouragement to reverse the negative streak, thus supporting the common-sense theory [2,10]. Lago-Peñas [10] found a higher percentage of points obtained after the change of coach in First and Second Spanish Division teams. However, this 'winning effect' was only a short-term solution. Contrary, several authors have not found performance improvements after the dismissal of the coach [6,7], and Balduck et al. [7] concluded that firing the coach is not the best way to deal with a performance dip. Tozetto et al. [11] examined the probability of coaches' survival in the top Brazilian football league between the seasons 2012 to 2017. The authors found that the median life of Brazilian league coaches was about 16 rounds, and only 26% of the coaches ended a season without being sacked, thus reflecting the ease of coaches are fired and potentially highlighting an excessive emphasis on short-term results to mediate club management decisions [11].

On the other hand, developing an appropriate physical capacity of players is paramount to achieve optimal performance [12,13]. It is logically understood that high-level soccer is highly demanding and players require an excellent fitness to withstand the competition demands. Therefore, monitoring the training- and match load of players is essential to attain good fitness and/or reduce the injury incidence [14–16]. In addition, the playing style proposed by the coach also affects the players' physical responses by position [17]. Castellano & Casamichana [18] showed that the coach turnover affected the teams' playing style, but found no difference in the distance covered between the dismissed coach (DC) and the new coach (NC). However, these authors did not consider the match status in the analysis, and could also affect players' physical responses in a competition [19,20]. Likewise, Lago-Peñas [5] found that players belonging to the Spanish first division showed a greater number of high-intensity bouts and precipitate decisions with an adverse score (i.e., losing the match) than with favorable score (i.e., winning) in competition.

The current literature often analyzes the effect of coach dismissal on the match score; winning, losing, or draw [5–7]. Changing the coach at mid-season is associated with poor team performance and it is often used as an 'escape route' to short-term improvements [7]. However, there is scarce research analyzing how the coach turnover affects players' physical responses both in training and competition. Knowledge of training- and match load variability between coaches could provide additional insight into the appropriateness of coach turnover, as well as being useful to practitioners for load monitoring and management when a NC arrives. Based on the literature analyzed, we assumed that the arrival of a NC may result in a positive stimulus for players in subsequent matches, and hence could be reflected in increased physical and physiological responses [5,10]. Therefore, the main purpose of this study was to analyze and compare the physical responses of professional players in the top three competitive standards of Spanish soccer (First Division, Second Division, and Second B Division) both in training and competition during the four weeks before and after the coach turnover.

Methods

Subjects

Training and match data across 3 professional soccer teams belonging to the top three competitive standards of Spanish soccer have been analyzed (n=1189 events): 25 professional players from First Division (D1) during the 2015-2016 season (22.8±0.8 yr; 177.8±6.9 cm; 73.3±5.7 kg); 25 players from Second Division (D2) during the 2017-2018 season (24.3±0.1 yr; 177.5±2.7 cm; 72.7±8.1 kg), and 25 players from Second B Division (D3) during the 2017-2018 season (21.4±0.6 yr; 177.5±6.1 cm; 70.8±0.8 kg). Players were classified by playing position [21–23]; central defender (CD), external defender (ED), central midfielder (CM), wide midfielder (WM) and forward (FO). The records were then divided by the coach's duration stages for further analysis (DC and NC). D1 and D3 teams had 2 coaches over the season, whereas 3 coaches trained the D2 team. However, data for the third coach of D2 were excluded from the analysis because this coach commenced at a very late stage of the season and trained the team for less than 4 weeks. It should be mentioned that teams from all divisions were in relegation positions when NCs began its job. Therefore, the rivals-teams to facing in matches were usually better ranked. Goalkeepers were excluded from the analysis.

The clubs and players were informed about the aim of this study, obtaining written consent by both on outlining the investigation purpose, which was performed in accordance with the ethical standards [24]. This study was approved by the University of Granada Ethics Committee (Number 471/CEIH/2018).

Instruments

Global positioning satellite systems (GPEXE Pro® 18.18 Hz, Udine, Italy) were used to collect the data for this study. The reliability and validity of these devices has been tested and verified recently [25,26] and GPS has been shown appropriate tools for load monitoring in soccer [22,27]. The players were fitted with these devices 15 minutes before the activity to avoid possible errors or delays with GPS' activations. The number of satellites during the training and matches was 8±1.

Variables

Metabolic and locomotion measures were collected to carry out this study. The metabolic metrics considered were [28,29]: average metabolic power (MP), on $W\cdot kg^{-1}$; average metabolic power of high-intensity actions, ≥20 $W\cdot kg^{-1}$, (MPev), on $W\cdot kg^{-1}$; number of high-intensity events (PowerE); maximal power reached during the activity

(Pmax), on $W \cdot kg^{-1}$; Equivalent Distance Index (EDI), on percentage, represents the ratio between the distance covered if the energy is expended at a constant speed, and the actual distance covered during the activity. Likewise, the locomotion activities considered were [21,30]: acceleration events (ACC), the number of speed increments equal or greater than 2 $m \cdot s^{-2}$, during an interval time equal or less than 0.5 seconds; deceleration events (DEC), the number of braking or speed decrements equal or less than - 2 $m \cdot s^{-2}$, during an interval time equal or less than 0.5 seconds; maximal speed reached during the activity (Vmax), on $km \cdot h^{-1}$; total distance covered (Total distance); walking distance, distance covered at speeds from 0 to 7 $km \cdot h^{-1}$; Low Speed Running Distance (LSRD), distance covered at speeds lower than 14 $km \cdot h^{-1}$; Medium Speed Running Distance (MSRD), from 14 to 18 $km \cdot h^{-1}$; High Speed Running Distance (HSRD), from 18 to 21 $km \cdot h^{-1}$; Very High Speed Running Distance (VHSRD), from 21 to 24 $km \cdot h^{-1}$; Sprint Running Distance (SPD), higher than 24 $km \cdot h^{-1}$. All evaluated distances have been recorded on meters.

Procedures

This observational study followed a cross-sectional and inferential design, therefore quantitative data presentation is mostly comparative in nature. To ascertain the effect of coach turnover and avoid the use of irrelevant data, the individual physical and metabolic responses of players were analyzed during 4 weeks before and 4 weeks after the coach dismissal [10] during the competitive period (from August to May). The data corresponding to preseason, Christmas period, and exclusively tactical training sessions (i.e. set pieces situations as corners or penalties) were excluded due to the possibility of variability in training records. Players who did not complete the entire training session and who participated in less than 80 minutes of match play were also excluded from the analysis.

Statistical Analysis

Microsoft Excel 2016 (Microsoft Corp, Redmond, Washington, USA) and SPSS for Mac (SPSS Inc., Chicago), version 25.0 was used. Training and match data were analyzed in isolation and differentiated by category (D1, D2, and D3). The Kolmogorov-Smirnov test revealed that all data were non-normally distributed. Therefore, non-parametric tests were consistently applied. Paired-samples Wilcoxon tests were used to compare the metabolic and locomotion responses of players between coaches (DC and NC). Then, to determine the meaningfulness of the difference between groups to improve the interpretation of the results, effect sizes (ES) using Cohen's *d* were calculated. Accordingly, we could say that this is a true measure of the significance of such a difference [31,32]. The magnitude of the ES were considered trivial (<0.20), small (0.20 to 0.50), moderate (0.50 to 0.80), or large (>0.80) [31]. Statistical significance was accepted at an alpha level of 0.01 for match data and 0.001 for training sessions to avoid inflation of the type-I error.

Results

Training

In training, the paired-samples test showed significant differences of locomotion activity parameters in the three categories analyzed (D1, D2 and D3) after the coach turnover expressed in relative terms (Table 1). In D1, small effects were found on EDI, ACCs, WalkD and HSRD (d=0.37, 0.39, 0.39 and 0.46, respectively; $p \leq 0.001$), and DC showed lower values than NC on EDI, ACCs and WalkD; while moderate effects were found on LSRD, MSRD, VHRSRD and SPD (d =0.52, 0.53, 0.58 and 0.54, respectively; $p \leq 0.001$), and DC showed higher MSRD, VHRSRD and SPD than NC. In D3, NC showed greater Vmax, EDI, WalkD and LSRD than DC (d =0.47 to 0.63, $p<0.001$); however, players showed greater distance covered for all speed ranges >14 $km \cdot h^{-1}$ with DC (small to moderate ES). Similar responses were found between coaches in D2, excepting on EDI and ACCs metrics, in which DC showed higher values (d =0.63, 0.50, respectively; $p<0.001$).

Match

Table 2 shows the comparative analysis (Wilcoxon test) of players' match responses between DC and NC in the three divisions expressed in relative terms. Scarce variances between metrics were found in the competition after the coach turnover compared to training. However, DC showed the greatest measures for all divisions: only VHSRD in D1 (2.6±0.8; d =1.03, $p<0.01$); EDI (15.4±3.1; d =0.69, $p<0.01$), ACCs (0.9±0.2; d =0.68, $p<0.01$) and DECs (1.0±0.4; d =0.61, $p<0.01$) in D2; and ACCs (0.9±0.1; d =0.73, $p<0.01$) in D3.

Tabla 8. Estudio 2 – [Table 1. Comparative analysis (Wilcoxon test) between DC and NC for metabolic and locomotion parameters in training. Data expressed in relative terms (means ± SD)].

	D1			D2			D3		
	DC (*n*=160)	NC (*n*=160)	*d*	DC (*n*=160)	NC (*n*=160)	*d*	DC (*n*=160)	NC (*n*=160)	*d*
MP ($W·kg^{-1}$)	6.5±0.8	6.4±1.0	0.11	6.0±1.0	6.0±1.1	0.01	6.6±1.6	6.3±0.8	0.01
EDI (%)	12.1±4.2	13.3±1.8	0.37†	14.4±2.0	13.0±2.4	0.63†	11.5±5.4	14.0±2.1	0.61†
PowerE ($events·min^{-1}$)	1.3±0.4	1.3±0.4	0.00	1.2±0.3	1.1±0.3	0.32	1.4±0.4	1.3±0.3	0.15
MPev ($W·kg^{-1}$)	28.2±2.5	28.1±1.4	0.05	21.1±1.9	21.3±1.4	0.13	24.7±6.0	23.2±3.2	0.31†
Vmax ($km·h^{-1}$)	26.3±3.1	25.4±2.6	0.31	27.6±3.5	27.3±2.8	0.10	23.4±8.6	26.4±2.6	0.47†
ACC ($events·min^{-1}$)	0.7±0.3	0.8±0.2	0.39†	0.9±0.3	0.7±0.2	0.50†	0.8±0.3	0.8±0.3	0.10
DEC ($events·min^{-1}$)	0.6±0.3	0.7±0.2	0.39	0.9±0.3	0.8±0.3	0.37	0.8±0.3	0.8±0.3	0.11
TotalD ($m·min^{-1}$)	75.4±9.8	73.3±11.2	0.20	82.4±11.7	83.1±12.5	0.05	76.9±31.0	83.0±10.4	0.26
WalkD ($m·min^{-1}$)	36.2±8.0	38.7±4.3	0.39†	41.2±4.3	40.7±4.0	0.12	38.8±8.0	42.7±3.4	0.63†
LSRD ($m·min^{-1}$)	57.2±12.7	62.9±9.1	0.52†	69.1±9.6	70.2±10.0	0.12	60.2±24.8	70.4±7.3	0.56†
MSRD ($m·min^{-1}$)	12.6±15.4	6.8±2.6	0.53†	7.6±3.0	7.8±2.7	0.06	15.2±14.2	8.0±2.9	0.70†
HSRD ($m·min^{-1}$)	3.3±2.8	2.3±1.3	0.46†	3.0±1.3	2.8±1.1	0.12	3.7±2.4	2.8±1.4	0.46†
VHSRD ($m·min^{-1}$)	1.4±1.0	0.9±0.7	0.58†	1.8±1.1	1.4±0.7	0.38	1.7±1.4	1.3±0.8	0.35†
SPD ($m·min^{-1}$)	0.9±1.2	0.4±0.5	0.54†	1.0±1.3	0.8±0.7	0.23	0.9±1.2	0.6±0.6	0.32†

p-value of Wilcoxon-Test: †$p \leq 0.001$. DC: Dismissed coach; NC: New coach; D1, Spanish First Division; D2, Spanish Second Division; D3, Spanish Second BDivision; MP, averaged Metabolic Power; ACC, acceleration events; DEC, deceleration events; Vmax, maximum speed; PowerE, Power events; MPev, Metabolic Power events average power; EDI, Equivalent Distance Index, on percentage; TotalD, total distance covered; WalkD, walk distance covered distance between 0 to 7 $km·h^{-1}$; LSRD, Low Speed Running Distance, covered distance lower than 14 $km·h^{-1}$; MSRD, Medium Speed Running Distance, covered distance between 14 to 18 $km·h^{-1}$; HSRD, High Speed Running Distance, covered distance between 18 to 21 $km·h^{-1}$; VHSRD, Very High Speed Running Distance, covered distance between 21 to 24 $km·h^{-1}$; SPD, Sprint Running Distance, covered distance higher than 24 $km·h^{-1}$.

Tabla 9. Estudio 2 – [Table 2. Comparative analysis (Wilcoxon test) between DC and NC for metabolic and locomotion parameters in match. Data expressed in relative terms (means ± SD)].

	D1			D2			D3		
	DC (*n*=40)	NC (*n*=40)	*d*	DC (*n*=40)	NC (*n*=29)	*d*	DC (*n*=40)	NC (*n*=40)	*d*
MP ($W·kg^{-1}$)	8.9±0.9	8.5±0.9	0.34	7.9±0.7	8.0±0.7	0.10	8.1±0.7	8.0±0.7	0.18
EDI (%)	12.2±1.3	11.5±1.6	0.38	15.4±3.1	13.5±1.2	0.69ˣ	13.7±1.4	13.5±1.2	0.13
PowerE ($events·min^{-1}$)	1.7±0.4	1.5±0.4	0.40	1.5±0.2	1.5±0.2	0.06	1.6±0.2	1.5±0.2	0.25
MPev ($W·kg^{-1}$)	29.4±2.2	28.5±1.2	0.41	22.0±1.4	22.0±0.9	0.00	22.1±0.9	22.0±0.9	0.10
Vmax ($km·h^{-1}$)	30.5±1.6	30.2±2.3	0.05	31.0±2.7	29.8±1.9	0.42	30.5±2.3	29.8±1.9	0.36
ACC ($events·min^{-1}$)	0.7±0.1	0.7±0.1	0.00	0.9±0.2	0.7±0.3	0.68ˣ	0.9±0.1	0.7±0.3	0.73ˣ
DEC ($events·min^{-1}$)	0.8±0.1	0.8±0.2	0.00	1.0±0.4	0.8±0.3	0.61ˣ	0.8±0.3	0.8±0.3	0.13
TotalD ($m·min^{-1}$)	102.7±11.2	98.3±10.6	0.30	104.6±8.1	107.8±7.7	0.30	109.5±8.6	107.8±7.7	0.11
WalkD ($m·min^{-1}$)	44.7±2.7	46.4±3.4	0.45	44.4±2.4	44.8±2.9	0.08	45.7±2.6	44.8±2.9	0.21
LSRD ($m·min^{-1}$)	82.0±7.5	80.8±5.1	0.09	81.5±6.2	84.1±5.0	0.36	85.7±5.5	84.1±5.0	0.20
MSRD ($m·min^{-1}$)	11.4±3.6	10.6±4.5	0.10	12.7±3.3	13.7±2.7	0.22	14.0±2.7	13.7±2.7	0.01
HSRD ($m·min^{-1}$)	4.7±1.4	3.9±1.7	0.41	5.1±1.6	5.1±1.0	0.02	5.3±1.2	5.1±1.0	0.13
VHSRD ($m·min^{-1}$)	2.6±0.8	1.7±0.8	1.03ˣ	2.9±1.2	3.0±0.7	0.03	2.6±0.8	3.0±0.7	0.33
SPD ($m·min^{-1}$)	2.0±0.8	1.3±0.9	0.72	2.3±1.2	1.9±1.0	0.24	1.8±0.8	1.9±1.0	0.13

p-value of Wilcoxon-Test: ˣ$p \leq 0.01$, †$p \leq 0.001$. DC: Dismissed coach; NC: New coach; D1, Spanish First Division; D2, Spanish Second Division; D3, Spanish Second BDivision; MP, averaged Metabolic Power; ACC, acceleration events; DEC, deceleration events; Vmax, maximum speed; PowerE, Power events; MPev, Metabolic Power events average power; EDI, Equivalent Distance Index, on percentage; TotalD, total distance covered; WalkD, walk distance covered distance between 0 to 7 $km·h^{-1}$; LSRD, Low Speed Running Distance, covered distance lower than 14 $km·h^{-1}$; MSRD, Medium Speed Running Distance, covered distance between 14 to 18 $km·h^{-1}$; HSRD, High Speed Running Distance, covered distance between 18 to 21 $km·h^{-1}$; VHSRD, Very High Speed Running Distance, covered distance between 21 to 24 $km·h^{-1}$; SPD, Sprint Running Distance, covered distance higher than 24 $km·h^{-1}$.

Discussion

The aim of this study was to compare the physical performance of professional players in the top three competitive standards of Spanish soccer both in training and competition during the four weeks before and after the coach dismissal. Players usually showed greater high-intensity activity with the DC in training. However, similar physical responses were found in matches before and after the coach turnover.

The importance of achieving a good physical capacity of players to withstand the competition demands is well known [12,13]. It is paramount that coaches develop an appropriate load programming and periodization for players in order to optimize performance and reduce the injury risks. Although changing the coach is a common practice after a negative streak of results [5–7], not much is known about how the coach turnover affects the players' physical performance. To the authors' knowledge, this is the only study analyzing the physical performance behavior of players in training after the coach dismissal. In this way, several differences between DC and NC were found in training. Contrary to our expectations, players usually showed greater physical responses with the DC than NC, especially in D1 and D3, in which players covered longer distance in all speed ranges >14 $km\cdot h^{-1}$ (MSRD, HSRD, VHSRD and SPD) with the DC. The authors initially raised the possibility of finding higher physical responses from players with the NC to gain a position in the starting line-up, especially those who were substitutes with DC. However, the reduced high-intensity activity found with the NC in training may be explained by the style of play proposed by the coach [18]. In this respect, Tierney et al. [17] analyzed movement patterns across the 5 most common playing formation (4-4-2; 4-3-3; 3-5-2; 3-4-3 and 4-2-3-1) in match play in England and found high variability between formations on the physical metrics developed by high-level players. For instance, the 3-5-2 formation showed the greatest total distance and high-intensity distance, and the greatest number of accelerations and decelerations was found in 4-2-3-1 formation. Moreover, players with the NC showed greater EDI than DC in D1 and D3. This metric represents the ratio of distance covered if the total energy is expended at a constant speed to the actual distance covered and is highly related with the ACCs and DECs events [29,33]. EDI involves more stop–start running, so the higher the EDI, the more intermittent the activity [34]. Therefore, the high EDI values could be due to long rest periods between efforts. However, the greater values of EDI along with the shorter high-intensity distance covered by players with the NC in training on D1 and D3 may also reflect the greater use of tasks in reduced spaces such as small-sided games, while large playing areas are needed to achieve high running speeds [35]. These opposite results found in training may suggest the use of different type of tasks by coaches; whereas the DC probably use large playing areas and thus reaching high speeds, the NC could apply training tasks based on reduced spaces. This could feature as an important consideration when hiring a NC as the players might need a progressive adaptation (physical and/or physiological) to reduce the injury risk [36]. Nonetheless, it should be noted that after firing the coach at mid-season the NC usually only has a few days before starting to compete and could prefer to focus on explaining and practicing the new game style to players, so the first training sessions or weeks could be oriented in favor of tactical preparation, such as 'automating' the motor patterns and correcting tactical errors. Indeed, it may also be supported by the fact that the players also covered a longer distance at low intensity with the NC (i.e., WalkD and LSRD). Either way, the playing style or tasks proposed by the coach affected the training physical responses of players [18].

In line with Castellano & Casamichana [18] who analyzed the 42 matches played by a team competing in the Spanish Second Division over a season and found no differences in the total distance covered during a match after the coach was dismissed, this study generally showed similar physical responses of players between the DC and NC in the match. Only a few significant differences found did not coincide between divisions; DC showed higher VHSRD in D1; EDI, ACC and DEC in D2; and ACC in D3. The rationale of finding similar performance among coaches in a match could be explained by the fact that only 4 matches were analyzed after the change of coach it might not be enough time for players to assimilate the new playing style and induce changes in the physical performance of players. Nonetheless, although not all results were significant, a trend of higher metrics was usually found with DC among categories, especially in D1 and D3. In addition, several contextual factors such as the quality of opposition [20,37,38], match status [19,20] or location [20,39] also affect the physical responses developed by players, and thus could have been more influential on the match physical performance than the coach turnover. However, they were not considered for analysis. Therefore, along with the generally higher physical responses of DC in training, there was no increase in the players' physical responses after the coach dismissal possibly being determined by a different style of play. It is also worth noting that the upcoming coach has to cope with the worst-case scenarios; the previous coach is usually fired after a negative streak of results and the NC has an urgent need to win, thus putting great pressure on him. Several authors have found a winning effect on match performance after dismissing the coach [2,5], whilst others authors argued that there is no causal relationship between improved match performance and a change of coach, and that 'recovery' from a negative streak of results occurs whether or not the coach is changed [6]. While the first authors consider that the coach turnover is a positive stimulus for the team [2,5], Heuer et al. [6] state that the change of coach is not the best approach to improve short-term results and only serves to placate frustrated stakeholders. This study did not analyze the effect of coach turnover on the likelihood of winning as only 4 training-weeks and matches before and after the coach dismissal were collected and also it was not the purpose of this study. However, the results suggest that changing the coach did not provide a positive stimulus to physical performance either: training sessions were generally more physically demanding with the DC and no major differences between coaches were found in the match. Therefore, the authors recommend that clubs should analyze in detail the rationale of changing the coach and what the new coach could provide, both in the tactical and physical aspects, since the coach turnover does not always mean a positive stimulus and can be a stressful phenomenon for players. Besides, players may also need a prolonged time to adapt to the specific demands of the new playing style and therefore may negatively affect player’s performance in the match.

This study has certain limitations. Firstly, the methodological design of this study focused on the 4 weeks before and 4 weeks after the coach dismissal, and data are only available for 3 teams. Moreover, factors as the quality of opposition or the specific playing style have not been considered in the analysis either. Therefore, further research is required with a larger number of teams and during a prolonged period of time to analyze the effect of a change of coach on the physical performance of players and its relationship with the match score, considering several factors such as the playing style or the quality of opposition, thus allowing clubs to facilitate the decision-making on whether to dismiss the coach is recommended or the specific considerations that the NC should take into account for the workload periodization in the first weeks.

Conclusions

The main finding of this study showed that players modify their behavior in relation to physical performance after the incorporation of a NC due to the dismissal of the previous coach at mid-season. In training, players showed greater high-intensity activity with the DC than NC. These results could be explained by the playing style or the different types of tasks proposed by coaches; whereas the DC probably used large playing areas and thus the players covered high-speed distances, the NC applied training tasks based on reduced spaces. On the other hand, a similar performance between coaches was found in the competition. However, only 4 matches may not be enough time for players to assimilate the new playing style and induce significant changes in the physical performance of players.

Practical Applications

It is a common practice in professional soccer to fire the coach at mid-season after a period of defeats for trying to reverse the negative streak. Understanding how the coach dismissal affects the behavior and physical performance of the players is useful for coaches and their technical staff to optimize load planning (volume and intensity of tasks) and avoid large changes that they could negatively affect the players' fitness. Furthermore, gaining good knowledge about the players' physical behavior could also help clubs determine whether the coach dismissal can provide a positive stimulus for players, or conversely be a stressful phenomenon.

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References

1. A.N. Turner, P.F. Stewart, Strength and conditioning for soccer players, Strength Cond J. 36 (4) (2014) 1–13.
2. P. Kattuman, C. Loch, C. Kurchian, Management succession and success in a professional soccer team, PLoS One. 14 (3) (2019) 1–20.

3. C. Lago-Peñas, J. Lago-Ballesteros, A. Dellal, M. Gómez, Game-Related Statistics that Discriminated Winning, Drawing and Losing Teams from the Spanish Soccer League. J Sports Sci Med. 9 (2) (2010) 288–93. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24149698
4. J. Castellano, D. Casamichana, C. Lago-Peñas, The Use of Match Statistics that Discriminate Between Successful and Unsuccessful Soccer Teams. J Hum Kinet. 31 (1) (2012) 139–47. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23487020
5. C. Lago-Peñas. Coach Mid-Season Replacement and Team Performance in Professional Soccer. J Hum Kinet. 28 (1) (2011) 115–22.
6. A. Heuer, C. Müller, O. Rubner, N. Hagemann, B. Strauss, Usefulness of dismissing and changing the coach in professional soccer. PLoS One. 6 (3) (2011) 1–7.
7. A.L. Balduck, M. Buelens, R. Philippaerts, Short-Term Effects of Midseason Coach Turnover on Team Performance in Soccer. Res Q Exerc Sport. 81 (3) (2010) 379–83. Available from: http://www.tandfonline.com/doi/abs/10.1080/02701367.2010.10599686
8. I.F. Kesner, T.C. Sebora, Executive Succession: Past, Present & Future. J Manage. 20 (2) (1994) 327–72.
9. W. Gamson, N. Scotch, Scapegoating in Baseball. Am J Sociol. 70 (1) (1964) 69–72. Available from: https://www.journals.uchicago.edu/doi/10.1086/223739
10. C. Lago-Peñas. Aplicación de la regresión lineal en el estudio del impacto del cambio de entrenador sobre el rendimiento en el fútbol. Eur J Hum Mov. 19 (2007) 145–63.
11. A.B. Tozetto, H.M. Carvalho, R.S. Rosa, F.G. Mendes, W.R. Silva, J.V. Nascimento, et al., Coach Turnover in Top Professional Brazilian Football Championship: A Multilevel Survival Analysis. Front Psychol. 10 (2019) 1246. Available from: https://www.frontiersin.org/article/10.3389/fpsyg.2019.01246/full
12. C. Barnes, D.T. Archer, B. Hogg, M. Bush, P.S. Bradley, The Evolution of Physical and Technical Performance. Int J Sports Med. 35 (13) (2014) 1095–100.
13. P.S. Bradley, D.T. Archer, B. Hogg, G. Schuth, M. Bush, C. Carling C, et al., Tier-specific evolution of match performance characteristics in the English

Premier League: it's getting tougher at the top. J Sports Sci. 34 (10) (2016) 980–7. Available from: http://www.tandfonline.com/doi/full/10.1080/02640414.2015.1082614

14. S. Malone, A.L. Owen, M. Newton, B. Mendes, K.D. Collins, T.J. Gabbett, The acute:chonic workload ratio in relation to injury risk in professional soccer. J Sci Med Sport. 20 (6) (2017) 561–5. Available from: http://dx.doi.org/10.1016/j.jsams.2016.10.014
15. A.L. Owen, J.J. Forsyth, D.P. Wong, A. Dellal, S.P. Connelly, K. Chamari, Heart Rate–Based Training Intensity and Its Impact on Injury Incidence Among Elite-Level Professional Soccer Players, J Strength Cond Res. 29(6) (2015) 1705–12. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25546452
16. T.J. Gabbett, The training—injury prevention paradox: should athletes be training smarter and harder? Br J Sports Med. 50 (5) (2016) 273–80. Available from: http://bjsm.bmj.com/lookup/doi/10.1136/bjsports-2015-095788
17. P.J. Tierney, A. Young, N.D. Clarke, M.J. Duncan, Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. Hum Mov Sci. 49 (2016) 1–8. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27269201
18. J. Castellano, D. Casamichana, Mismos jugadores con diferentes entrenadores, ¿se puede jugar de manera diferente para optimizar el rendimiento en el fútbol profesional? Sport TK-Revista Euroam Ciencias del Deport. 5 (2) (2016) 133.
19. M. Andrzejewski, P. Chmura, M. Konefał, E. Kowalczuk, J. Chmura, Match outcome and sprinting activities in match play by elite German soccer players, J Sports Med Phys Fitness. 58 (6) (2017) 785–92.
20. C. Lago-Peñas, E. Rey, J. Lago-Ballesteros, L. Casáis, E. Domínguez, The influence of a congested calendar on physical performance in elite soccer. J strength Cond Res. 25 (8) (2011) 2111–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21572352
21. A. Martín-López, R.S. Mendes, A. Castillo-Rodríguez, Internal and External Loads in Training Week Before the Competition in U19 High-Level Soccer Players, J strength Cond Res. 00 (00) (2018) 1–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/30557176
22. J. Malone, R. Di Michele, R. Morgans, D. Burgess, J. Morton, B. Drust, Seasonal

training-load quantification in elite English premier league soccer players. Int J Sports Physiol Perform 10 (4) (2015) 489–97. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25393111

23. A.L. Owen, C. Lago-Peñas, M.Á. Gómez, B. Mendes, A. Dellal A, Analysis of a training mesocycle and positional quantification in elite European soccer players. Int J Sport Sci Coach 12 (5) (2017) 665–76.
24. D.J. Harriss, A. MacSween, G. Atkinson, Ethical Standards in Sport and Exercise Science Research: 2020 Update. Int J Sports Med. 40 (13) (2020) 813–7. Available from: http://www.thieme-connect.de/DOI/DOI?10.1055/a-1015-3123
25. P. Terziotti, M. Sim, T. Polglaze, A comparison of displacement and energetic variables between three team sport GPS devices. Int J Perform Anal Sport. 18 (5) (2018) 823–34. Available from: https://doi.org/10.1080/24748668.2018.1525650
26. M.W. Hoppe, C. Baumgart, T. Polglaze, J. Freiwald, Validity and reliability of GPS and LPS for measuring distances covered and sprint mechanical properties in team sports. PLoS One. 13 (2) (2018) e0192708
27. A.L. Owen, L. Djaoui, M. Newton, S. Malone, B. Mendes, A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer. Sci Med Footb. 3938 (July) (2017) 1–6. Available from: https://www.tandfonline.com/doi/full/10.1080/24733938.2017.1334958
28. P.E. Di Prampero, A. Botter, C. Osgnach. The energy cost of sprint running and the role of metabolic power in setting top performances. Eur J Appl Physiol. 115 (3) (2015) 451–69. Available from: http://link.springer.com/10.1007/s00421-014-3086-4
29. C. Osgnach, S. Poser, R. Bernardini, R. Rinaldo, P.E. Di Prampero, Energy cost and metabolic power in elite soccer: A new match analysis approach. Med Sci Sports Exerc. 42 (1) (2010) 170–8.
30. D. Casamichana, J. Castellano, Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. J Sports Sci. 28 (14) (2010) 1615–23. Available from: http://www.tandfonline.com/doi/abs/10.1080/02640414.2010.521168
31. J. Cohen, Statistical power analysis for the behavioral sciences. In Routledge (1988).
32. R. Coe, C. Merino, Magnitud del efecto: Una guía para investigadores y usuarios.

Rev Psicol a – PUCP. 21 (1) (2003) 147–77.

33. T. Polglaze, M.W. Hoppe, Metabolic Power: A Step in the Right Direction for Team Sports. Int J Sports Physiol Perform. 14 (3) (2019) 407–11. Available from: https://journals.humankinetics.com/doi/10.1123/ijspp.2018-0661
34. T. Polglaze, B. Dawson, P. Peeling, Gold Standard or Fool's Gold? The Efficacy of Displacement Variables as Indicators of Energy Expenditure in Team Sports. Sport Med. 46 (5) (2016) 657–70.
35. D. Castillo, A. Rodríguez-Fernández, F.Y. Nakamura, J. Sanchez-Sanchez, R. Ramirez-Campillo, J. Yanci , et al, Influence of Different Small-Sided Game Formats on Physical and Physiological Demands and Physical Performance in Young Soccer Players. J Strength Cond Res 1 (2019).
36. N. James, Coaching Experience, Playing Experience and Coaching Tenure: A Commentary. Int J Sports Sci Coach. 2 (2) (2007) 109–40.
37. E. Rampinini, A.J. Coutts, C. Castagna, R. Sassi, F. Impellizzeri, Variation in Top Level Soccer Match Performance. Int J Sports Med. 28 (12) (2007) 1018–24. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17497575
38. J. Castellano, A. Blanco-Villaseñor, D. Álvarez, Contextual Variables and Time-Motion Analysis in Soccer. Int J Sports Med. 32 (06) (2011) 415–21. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21590641
39. M. Mohr, P. Krustrup, J. Bangsbo, Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci. 21 (7) (2003) 519–28. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12848386

Estudio 3

How does the workload applied during the training week and the contextual factors affect the physical responses of professional soccer players in the match?

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How does the workload applied during the training week and the contextual factors affect the physical responses of professional soccer players in the match?

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ABSTRACT

The aim of this study was to examine whether match physical output can be predicted from the workload applied in training by professional soccer players. Training and match load records from two professional soccer teams belonging to the Spanish First and Second Division were collected through GPS technology over a season (*N*=1678 and *N*=2441 records, respectively). The factors playing position, season period, quality of opposition, category and playing formation were considered into the analysis. The level of significance was set at $p \leq .05$. The prediction models yielded a conditional R-squared in match of 0.51 in total distance (TD); 0.58 in high-intensity distance (HIRD, from 14 to 24 $km \cdot h^{-1}$); and 0.60 in sprint distance (SPD, >24 $km \cdot h^{-1}$). The main finding of this study was that the physical output of players in the match was predicted from the training-load performed during the previous training week. The training-TD negatively affected the match physical output while the training-HIRD showed a positive effect. Moreover, the contextual factors - playing position, season period, division and quality of opposition - affected the players' physical output in the match. Therefore, these results suggest the appropriateness of programming lower training volume but increasing the intensity of the activity throughout the weekly microcycle, and considering contextual factors within the load programming.

Key words: monitoring; GPS; periodization; workload; football; performance

INTRODUCTION

Soccer is a complex sport with a myriad of factors that may affect players' physical performance [1–4]. Competing at a high-level is increasingly challenging and players must attain optimal physical readiness to withstand the competition demands [5,6]. Therefore, monitoring and quantifying the players' workload is paramount to optimising performance and reducing the injury risk [7,8]. Accordingly, the application of global positioning system (GPS) data for external-load monitoring is commonly used in professional soccer, as it allows coaches to evaluate the effectiveness of the training intervention on a daily basis [9]. The analysis of locomotion parameters provides tangible information on physical activity in soccer. However, it is important to note that situational variables significantly affect players' physical responses and must be taken into account for load programming, such as the training-day into the weekly microcycle, the differences responses by playing position or the playing style proposed by the team. In this sense, several authors have found that the greatest training load (TL) is concentrated in the middle days of microcycle (4 and 3 days before the match) and progressively decrease until one day before the match [10,11], in addition the physical demands developed by players vary according to the playing position [8,10,12]. Likewise, the playing style or the different technical skills also affect the physical output of players, either in prompt responses or considering the whole match (e.g., accumulated fatigue) [13,14]. For instance, Tierney et al. [14] compared the physical responses across the 5 most common playing formations (4-4-2; 4-3-3; 3-5-2; 3-4-3 and 4-2-3-1) in match play in professional youth soccer players and found large load differences between formations; the 3-5-2 formation showed the greatest total distance and high-intensity distance, and the 4-2-3-1 the greatest number of accelerations and decelerations.

On the other hand, there are also contextual factors that affect the physical responses of players in competition: the quality of opposition [5,15,16], match location [5,17], match score [18,19] or the season period [15,17] are some of the most analysed factors. In overall, playing against top-teams elicit higher physical demands, covering greater total distance and high-intensity distance; home teams covered a greater total distance and low intensity distance; teams with an adverse match score-line showed higher physical responses than their opponents; and players showed different performance between periods of the season, although there are currently discrepancies in the literature regarding the most physically demanding period. Moreover, recent studies have analysed how these contextual factors affected the load across the training week [1–3]. Rago et al. [3] found higher total distance and high-intensity distance in the training-week after an away-match and after playing against a weak team. In contrast, Brito et al. [1] showed lower load on the training-week before and after playing against a top team. Recently, Guerrero-Calderón et al. [2] showed higher TL within the training week when the upcoming match was away and against a top opponent. In addition, these authors found a decrease in all TL measures from the start to the middle period of the season, and a further decrease from the middle to the end of the season in high-level players. In accordance with the results, the abovementioned authors argued the need to consider the contextual factors within the TL programming.

Players require an increased physical capacity to cope with the competition demands. In this sense, it is of paramount importance to design specific workload programs for players according to the playing position, quality of opposition, match location or season period, among others. To the authors' knowledge, it would be useful for coaches to determine how the workload realised during the training week will affect the physical output of the upcoming match in order to ascertain the level of 'readiness' of the players for the match load. Based on previous studies, the weekly TL greatly affects the match load [11,12,20]. Our hypothesis is that the load showed by players on match day (MD) can be predicted from the TL realised during the weekly microcycle immediately before the match. In addition, the influence of contextual factors on physical output, the factors season period, quality of opposition, playing style and category will be considered within the predictive models. Therefore, this study aimed to examine whether the match physical output can be predicted from the TL realised during the previous training-week on professional soccer players. Subsequently, it was determined how the match load affects the match-score and, if so, how it can be explained by TL.

METHODS

Participants and sample

Training and match load data across two male professional soccer teams belonging to the Spanish First and Second division (D1 and D2, respectively) were analysed in this study: thirty players from D1 during the 2015-2016 season (22.8±0.8 yr; 177.8±6.9 cm; 73.3±5.7 kg) and twenty-six players from D2 during the 2017-2018 season (24.3±0.1

yr; 177.5±2.7 cm; 72.7±8.1 kg). Only the records for single-match weeks with at least 4 team training sessions before an official League match during the competitive period were considered within the analysis. Thus, a total of 29 matches and 33 training weeks (for training data) were collected from D1; and 33 matches and 41 training weeks from D2. The data corresponding to preseason, Christmas period, microcycles with two weekly matches and exclusively tactical training sessions (e.g., set pieces) were excluded from the analysis in order to avoid variability in training records. The records of players who did not complete the full training session and those who participated in less than 80 minutes of match play were neither consider. Each of the 4119 initial records (1678 from D1 and 2441 from D2) correspond to training-sessions or match per player. All records were aggregated per player and per week. Accordingly, one observation corresponded to the training and match load during a single week by player. Only weeks where the respective player was recorded for at least three training sessions and one match were considered within the analysis. This resulted in 141 observations of players in distinct weeks, from which two had to be discarded because of missing data. The remaining 139 observations stemmed from 26 players and 26 distinct training weeks. Therefore, as the number of training records was not the same every week, the TL data per week was aggregated by averaging the TL over the number of training sessions recorded. This data set was used for statistical analysis.

In terms of playing formation, the D1-team used the 4-5-1 formation on 22 matches, 4-4-2 on 8 matches, 4-3-3 in 7 matches and 3-4-3 in 1 match; and the D2-team used the 4-5-1 formation in 35 matches, 4-4-2 in 4 matches and 4-3-3 in 3 matches.

The Club and players were informed about the aim of this study, and both obtained consent. This study was approved by the University of Granada Ethics Committee (Number 471/CEIH/2018). It complied with the ethical standards of the University and followed the guidelines of the Declaration of Helsinki (2013).

Instruments

GPS technology (GPEXE Pro® 18.18 Hz, GPEXE, Udine, Italy) was used to collect data for this study. These devices have proven to be a valid and reliable tool for daily load-monitoring in soccer [7,8,22]. To avoid inter-unit errors, each player used the same GPS unit in all training sessions and matches [7,8,22].

Variables

Physical responses

The following locomotion metrics were collected for analysis: total distance covered (TD); high-intensity running distance (HIRD), which is the total distance covered at speeds >14 $km \cdot h^{-1}$); and sprint running distance (SPD), considering only the distance covered at speed higher than 24 $km \cdot h^{-1}$. Training (t-TD, t-HIRD and t-SPD) and match metrics (m-TD, m-HIRD and m-SPD) were differentiated for analysis. All distances were recorded in meters.

Contextual factors

Both training and match records were classified according to the *season period*; from August to November (Start), December to February (Middle) and March to May (Final) [6,15,17]; *quality of opposition*, differentiating the teams according to their League ranking at the end of the previous match-week [1,2]: 'Top-teams' (1^{st} to 6^{th} on D1, and 1^{st} to 7^{th} on D2), 'Medium-teams' (7^{st} to 14^{th} on D1, and 8^{st} to 15^{th} on D2) and 'Weak-teams' (15^{st} to 20^{th} on D1, and 16^{st} to 22^{th} on D2); *playing position*, classified by central defenders (CDs), external defenders (EDs), central midfielders (CMs), wide midfielders (WMs) and forwards (FOs) [7,12,21] (goalkeepers were not considered); *division*, D1 and D2; and *playing formation*, differentiating by 4-5-1 formation, 4-4-2 and 4-3-3. The 3-4-3 formation data was deleted as it was only used in a single match.

Statistical Analysis

R Studio (version 3.6.1; R Core Team, 2019) was used for data processing and statistical analyses. In order to examine the relationship between the TL and the match physical output, linear mixed effects models were fit for three different dependent variables: m-TD, m-HIRD and m-SPD. As fixed effects, we entered five contextual factors (division, quality of opposition, playing position, formation used by the team and season period) as well as two TL variables (t-TD and t-HIRD) into the model. Since the SPD is a subset of the HIRD, we only include t-HIRD to avoid collinearity of results. Actually, the correlation between t-HIRD and t-SPD amounted to $r(137) = .35$ ($p < .001$). Similar, m-HIRD and t-SPD were also correlated with $r(137) = .56$ ($p < .001$). By the nature of the collected data, the assumption of independence between observations was violated (players were observed multiple times and multiple players participated in the same matches), so mixed effects models were used and the players were modelled as random effects, using random intercept-only models. However, the inter-dependency of observations cannot be fully overcome. Testing of fixed effects was done using Likelihood Ratio Tests [23,24]. Conditional R^2 (R^2_c) was calculated following the calculations of Nakagawa and Schielzeth [25]. The linear mixed effects analysis was done using the lme4 package [26].

RESULTS

The parameter estimates for the linear mixed models of the total distance (m-TD), high-intensity running distance (m-HIRD) and sprint distance covered in match (m-SPD) are shown in Table 1.

Tabla 10. Estudio 3 – [Table 1. Parameters estimates and p-values of predictors for linear mixed models of the total distance (m-TD), high-intensity running distance (m-HIRD) and sprint distance covered in match (m-SPD). p-values are obtained from Likelihood Ratio Test. (Var., variable; SD, standard deviation)].

	m-TD model		m-HIRD model		m-SPD model	
Fixed effects	*Estim.*	*p*	*Estim.*	*p*	*Estim.*	*p*
(Intercept)	9051.07	-	1314.97	-	18.31	-
division [2]	437.93	.07	331.48	.002	58.47	.03
quality of opposition [medium]	-338.08	.07	-167.41	.04	-14.76	.08
quality of opposition [top]	-60.75	.07	32.00	.04	28.52	.08
playing position [ED]	33.22	.001	172.34	<.001	53.40	.001
playing position [CM]	1122.85	.001	769.01	<.001	-8.67	.001
playing position [WM]	304.26	.001	578.76	<.001	136.78	.001
playing position [FO]	-288.87	.001	338.26	<.001	102.99	.001
formation [4-4-2]	235.45	.56	48.60	.56	41.28	.09
formation [4-5-1]	222.95	.56	126.08	.56	57.46	.09
season period [middle]	714.12	.001	320.53	.003	38.30	.001
season period [end]	646.45	.001	337.64	.003	107.50	.001
t-TD	-0.36	.004	-0.18	.003	-0.04	.006
t-HIRD	1.06	.004	0.76	<.001	0.18	<.001
Random effects	*Var.*	SD	*Var.*	*SD*	*Var.*	*SD*
Player (Intercept)	134040	366.1	11617	107.8	1672	40.9
Residual	384986	620.5	102656	320.4	4815	69.4

Total distance

The average TD covered by players per match was 9298 m (± 871 m). The distance covered with respect to the contextual factors is shown in Figure 1.

The model of m-TD yielded a R^2_c of .51. The random effects of players accounted for approximately 17.7% of the variance in m-TD. Likelihood ratio tests of predictors indicated significant fixed effects of playing position, $\chi^2(4)=17.89$, p=.001; season period $\chi^2(2)=13.75$, p=.001; t-TD, $\chi^2(1)=8.29$, p=.004; and t-HIRD, $\chi^2(1)=8.42$, p=.004. Therefore, the season period and playing position significantly affected m-TD. In addition, both t-TD and t-HIRD significantly affected m-TD; t-TD showed a slight negative effect, and t-HIRD had a positive effect on m-TD. Figure 2 shows the relationship between m-TD and t-HIRD.

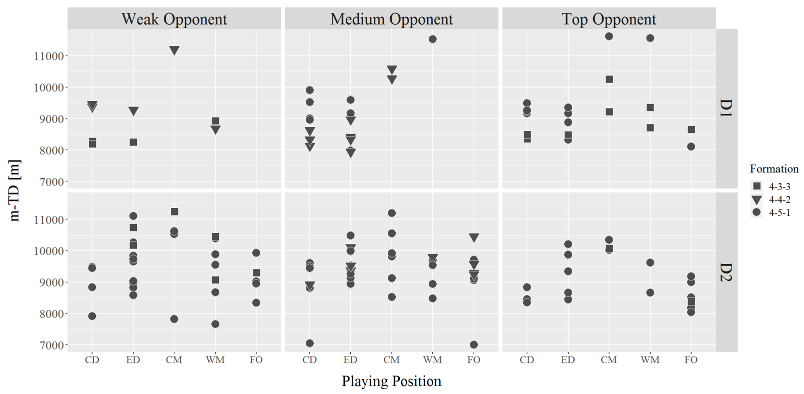

Figura 4. Estudio 3 – [Figure 1. Total distance covered by players during the match considering the contextual factors division, playing position, opponent quality and playing formation].

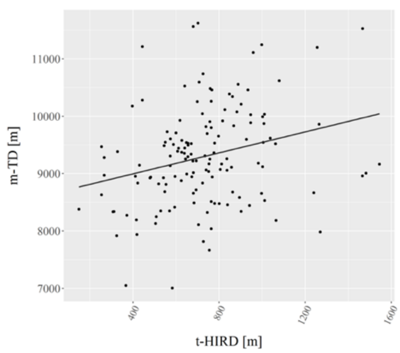

Figura 5. Estudio 3 – [Figure 2. Total distance covered during the match as a function of high-intensity running distance covered during training in the week before the match. Each point represents the record of one player a single week. The linear mixed effects analysis yielded an R^2_C of .51 for the m-TD model].

High-intensity distance

Players in this study covered on average 1880 m (± 501 m) of HIRD per match. The effect of the contextual factors on m-HIRD is shown in Figure 3.

The R^2_c of the m-HIRD model was .58. The random effects of players accounted for approximately 4.6% of the variance in m-HIRD. Likelihood Ratio Tests of predictors indicated significant fixed effects of division, $\chi^2(1)=9.66$, $p=.002$; quality of opposition, $\chi^2(2)=6.68$, $p=.04$; playing position, $\chi^2(4)=31.43$, $p<.001$; season period, $\chi^2(2)=11.36$, $p=.003$; t-TD, $\chi^2(1)=8.63$, $p=.003$; and t-HIRD, $\chi^2(1)=16.05$, $p<.001$. Thus, the contextual factors division, quality of opposition, season period and playing position significantly affected the m-HIRD. On the other hand, t-TD showed a slight negative effect on m-HIRD while the t-HIRD had a positive effect. Figure 4 shows the relationship between the HIRD covered in match and in training.

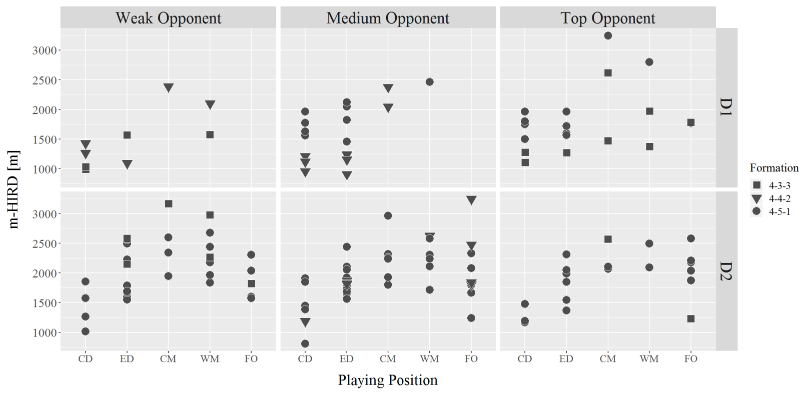

Figura 6. Estudio 3 – [Figure 3. High-intensity running distance covered by players during the match considering the contextual factors division, playing position, opponent quality and playing formation].

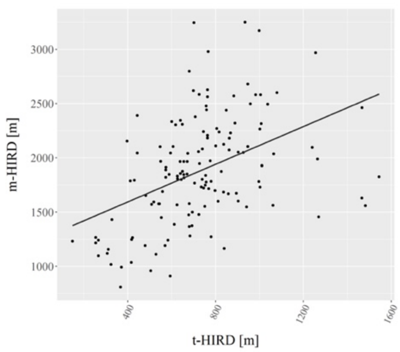

Figura 7. Estudio 3 – [Figure 4. High-intensity running distance covered during the match as a function of high-intensity running distance covered during training in the week before the match. Each point represents the record of one player a single week. The linear mixed effects analysis yielded an R^2_C of .58 for the m-HIRD model].

Sprint distance

Players in this study covered on average 176 m (± 109 m) m-SPD per match. The distance covered with respect to the contextual factors is shown in Figure 5.

The R^2_c of the m-SPD model was .60. The random effects of players accounted for approximately 14% of the variance in m-SPD. Likelihood Ratio Tests of predictors indicated significant fixed effects of division, $\chi^2(1)=4.82$, $p=.03$; playing position, $\chi^2(4)= 18.29$, $p=.001$; season period, $\chi^2(2)=13.1$, $p=.001$; t-TD, $\chi^2(1)=7.4$, $p=.007$; and t-HIRD, $\chi^2(1)=18.57$, $p<.001$. Thus, the contextual factors division, season period and playing position significantly affected m-TD. Besides, the m-SPD was negatively affected by m-TD, and positively affected by t-HIRD. Figure 6 shows the relationship between m-SPD and t-HIRD.

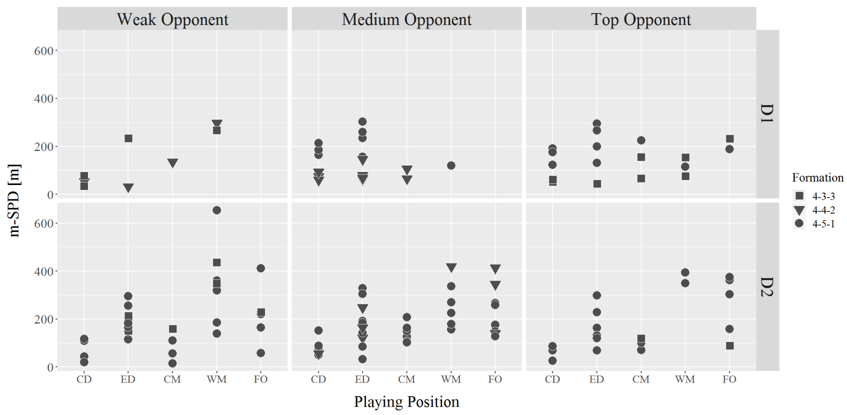

Figura 8. Estudio 3 – [Figure 5. Sprint distance covered by players during the match considering the contextual factors division, playing position, opponent quality and playing formation].

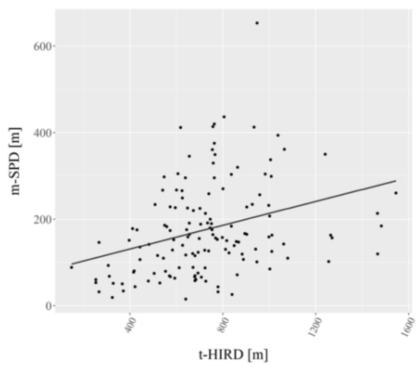

Figura 9. Estudio 3 – [Figure 6. Sprint distance covered during the match as a function of high-intensity running distance covered during training in the week before the match. Each point represents the record of one player a single week. The linear mixed effects analysis yielded an R^2_C of .6 for the m-SPD model].

DISCUSSION

The aim of the present study was to examine whether the physical match performance can be predicted from the workload realised by professional soccer platers across the previous training week. The main finding was that both the total distance, high-intensity running distance and sprint distance covered in match by players showed strong relationships to TL realised during the previous week (t-TD and t-HIRD). Accordingly, a common feature of all the metrics was that t-TD negatively affected the physical output of the match, while t-HIRD showed a positive effect. Furthermore, the contextual factors affected on match physical responses: the playing position and season period affected in all match physical variables, the m-HIRD was affected by quality of opposition whereas the m-HIRD and m-SPD differed between divisions.

The monitoring and quantification of TL is of paramount importance in professional soccer to optimize the physical capacity of players and prevent injuries [9,27]. In this regard, the design of individualized training programs based on the specific competition demands represents a good strategy to optimize the training periodization [11]. However, although there is a widespread belief among practitioners that 'players compete as they train', a recent study conducted with semi-professional soccer players questioned the appropriateness of the TL applied across the microcycle due to the high variability of physical and physiological responses found between training sessions and official matches, and finally the authors concluded that players do not train as they compete [28]. Nonetheless, although no appropriate TL has been established at present, the main physical objective of training is to prepare players to withstand the competition demands [29]. Accordingly, the present investigation found that the TD covered by players during the previous training week negatively affected their physical output in the upcoming match: for every meter of TD covered in training, players covered 0.36, 0.18 and 0.04 m less TD, HIRD and SPD respectively, in the match. Contrarily, t-HIRD showed a positive effect: for every meter of HIRD that players showed in the preceding training week, they covered 1.06, 0.76 and 0.18 m more TD, HIRD and SPD respectively, in the match. These results could be interpreted as: players should develop a limited volume of training (i.e., TD), while those training sessions should present a greater activity of high-intensity. Soccer is a high-intensity activity characterized by the alternation of intermittent efforts [4]. Although several authors have argued that players may reduce their match physical output after developing a high load volume (i.e., TD) in the previous training week [10,11], players should develop a high enough HIRD over the training week to achieve good readiness for competition [30]. However, coaches should be prudent about programming the high-intensity activity of players and avoid excessive TLs and long training sessions the day before the match [30], as an excessive load may increase the players' fatigue and subsequently damage their physical capacity and increase the injury risk [10,11]. In this sense, a recent systematic review showed that very high-intensity distance caused changes in the muscle-damage markers (e.g., creatine kinase) 24 hours after activity [31]. Furthermore, coaches should also take into account the individual players' accumulated load when programming the workload in order to avoid load spikes, which are considered to be a substantial risk factor [32,33]. Therefore, these results suggest the importance of load periodization over the microcycle and the progressive exposure to higher workloads.

In recent years, an increased number of studies have also highlighted the importance to contextualize the load monitoring [1–3]. This study aimed to determine whether the match physical output can be predicted from the TL considering several contextual factors such as playing position, season period, playing style or quality of opposition within the analysis. The factors playing position and season period affected the physical responses analysed in competition (i.e., m-TD, m-HIRD and m-SPD). The high workload variability existing between playing positions is well established [11,12]. In line with other authors, CM was one of the most physically demanding positions [7,10]. Accordingly, CMs showed the greatest TD and HIRD compared to other positions. However, the CMs also covered the lower SPD. Thus, special emphasis should be placed on ensuring proper load programming by designing specific tasks with the types of effort and locomotion activities demanded by position in the match [11,12]. Concerning to the workload developed by players in match across the season, this study showed variability between the different metrics analysed: whereas players covered a greater m-TD in the middle period compared to the other periods, the highest m-HIRD and m-SPD were found in the final period of the season. The literature shows controversy about the season period: several authors showed higher total distance and high-intensity distance covered in the final period compared to the first and middle period [15,17], Guerrero-Calderón et al. [2] found the greatest TL in the middle period, whereas other authors have found no significant TL variations over the season [7]. These discrepancies between authors may be due to the different leagues analysed; Mohr et al. [17] and Rampinini et al. [15] analysed the Italian First Division, J. Malone et al. [7] analysed the English Premier League, Guerrero-Calderón et al. [2] analysed the Spanish First Division and the present study was performed with Spanish First and Second Division teams. Nonetheless, these results also showed the lowest values in the initial period for all metrics (m-TD, m-HIRD and m-SPD). This may be interpreted by the fact that the players just completed the preseason and are still gradually improving their physical capacity [17]. Similarly, the results found that the division-factor affected HIRD and SPD in the match. It therefore suggests the importance of contextualizing the load in order to consider the specific demands of the category concerned. On the other hand, several authors concluded that environmental temperature or humidity may play an important role for exercise performance [15,34,35]. Accordingly, very hot or cold air temperature or high humidity may negatively affect the physical responses of soccer players due to high thermal stress. Although this factor was no considered in the study, the variability found in the physical output between season periods may be also due to environmental factors. Nonetheless, it should be noted that soccer players from different countries and competitions may have different best comfort zones of air temperature and humidity [15]. Within the workload contextualization the playing style is another important factor. Contrary to Tierney et al. [14], who found significant differences in the physical responses according to playing style, the present study showed that the different formations used by teams during the season did not affect the players' physical responses [36,37]. It should be noted that the analysed teams used the same playing system in almost all matches and only changed the formation a few times during the season. This may be interpreted as occasional variations in formation are not enough to cause changes in players' physical responses, as they might need a longer period of learning and adaptation to new stimuli of the playing system [38]. Finally, the quality of opposition is another factor that greatly affects the players' physical performance in competition [16,19,39]. These results showed that the quality of opposition significantly affected the m-HIRD, although it did not affect the m-TD and m-SPD. Competing against the best teams is more physically demanding and involves covering a longer distance [2,39]. However, some authors have concluded that the effect of this factor on physical performance is due to variations in the technical-tactical aspects [16,39]. For instance, Lago-Peñas et al. [39] showed that best teams normally have greater percentage of ball possession, and consequently playing against them involves covering higher TD without the ball in the attempt to regain the possession. While the previous author found variability in the TD, this study showed no differences in m-TD and m-SPD. The increased HIRD and similar TD showed in matches when competing against top teams may be explained for reasons such as these teams are able to move the ball faster or achieve a better defensive position on the field, so more intense efforts are needed when playing against these teams [40]. Therefore, coaches must consider the quality of opposition together with other contextual factors within the workload programming to attain a good readiness of players to withstand the match demands. However, although these results showed that the contextualized workload developed by players during the training week strongly affected their physical output in the match, further research should attempt to analyse a larger number of teams from different leagues and countries. Furthermore, it would be useful to take into account technical-tactical aspects within the analysis in order to define the specific profiles by position.

CONCLUSIONS

The main finding of this study was that the physical responses developed by players in the match (m-TD, m-HIRD and m-SPD) were predicted from the workload performed during the training week before the match. In this sense, the TD covered in training showed a negative effect in the match physical output whereas the t-HIRD showed a positive effect. Therefore, these results suggest the appropriateness of reducing the volume of training sessions in order to cover less TD, but increasing the intensity or speed of the activity, meaning low TD and high HIRD. Accordingly, the HIRD metric was considered the most determinant physical metric. Finally, the contextual factors playing position, season period, division and quality of opposition showed a strong effect on match performance and thus they must consider within workload programming. These contextual factors should not be analysed in isolation as these factors may affect one another.

PRACTICAL APPLICATIONS

Gaining knowledge about how the workload developed by professional players during the training week and situational variables affect their physical output in the match is really useful for technical staff to interpret the TL properly. In this regard, the intensity of training should be high while the volume should be kept low in order to achieve an increased physical output in the upcoming match. This means covering an elevated HIRD without covering too much total distance during the training week before the match. Accordingly, if players cover an additional 400 meters of HIRD during the training week, it is estimated to increase 424, 304 and 72 m of TD, HIRD and SPD respectively in the upcoming match. However, these 400 m should not increase the total distance covered by the players. In addition, practitioners must take special consideration of contextual factors. For instance, in those scenarios when a team is facing top teams near to the end of the season, the HIRD requirements are higher compared to playing against lower-ranked opponents or when the match is the initial period of the season. Furthermore, by collecting data from individual players throughout the season, practitioners can predict what the load pattern will be in the match. This information is very useful for coaches as it provides insight into the players' level of 'readiness' to cope with the match demands and how the TL affects match load considering different contextual factors.

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REFERENCES

1. Brito J, Hertzog M, Nassis GP. Do Match-Related Contextual Variables Influence Training Load in Highly Trained Soccer Players? *J Strength Cond Res* 2016; 30(2): 393–399.
2. Guerrero-Calderón B, Klemp M, Castillo-Rodriguez A, Morcillo JA, Memmert D. A New Approach for Training-Load Quantification in Elite-Level Soccer: Contextual Factors. *Int J Sports Med* 2020; 41: 1–9.

3. Rago V, Rebelo A, Krustrup P, Mohr M. Contextual Variables and Training Load Throughout a Competitive Period in a Top-Level Male Soccer Team. *J Strength Cond Res* 2019; (25):1.
4. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. *Sports Med* 2005; 35(6): 501–536.
5. Lago-Peñas C, Rey E, Lago-Ballesteros J, Casáis L, Domínguez E. The influence of a congested calendar on physical performance in elite soccer. *J strength Cond Res* 2011; 25(8): 2111–2117.
6. Dellal A, Lago-Peñas C, Rey E, Chamari K, Orhant E. The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. *Br J Sports Med* 2015; 49(6): 390–394.
7. Malone J, Di Michele R, Morgans R, Burgess D, Morton J, Drust B. Seasonal training-load quantification in elite English premier league soccer players. *Int J Sports Physiol Perform* 2015; 10(4): 489–497.
8. Owen AL, Djaoui L, Newton M, Malone S, Mendes B. A contemporary multi-modal mechanical approach to training monitoring in elite professional soccer. *Sci Med Footb* 2017; 3938(July): 1–6.
9. Cardinale M, Varley MC. Wearable Training-Monitoring Technology: Applications, Challenges, and Opportunities. *Int J Sports Physiol Perform* 2017; 12(Suppl 2):S255–S262.
10. Clemente FM, Owen AL, Serra-Olivares J, Nikolaidis PT, Van Der Linden CMI, Mendes B. Characterization of the Weekly External Load Profile of Professional Soccer Teams from Portugal and the Netherlands. *J Hum Kinet* 2019; 66(1): 155–164.
11. Martín-García A, Gómez Díaz A, Bradley PS, Morera F, Casamichana D. Quantification of a professional football team's external load using a microcycle structure. *J Strength Cond Res* 2018; 32(12): 3511–3518.
12. Owen AL, Lago-Peñas C, Gómez MÁ, Mendes B, Dellal A. Analysis of a training mesocycle and positional quantification in elite European soccer players. *Int J Sport Sci Coach* 2017; 12(5): 665–676.
13. Bradley PS, Ade JD. Are Current Physical Match Performance Metrics in Elite Soccer Fit for Purpose or Is the Adoption of an Integrated Approach Needed? *Int J Sports Physiol Perform* 2018; 13(5): 656–664.

14. Tierney PJ, Young A, Clarke ND, Duncan MJ. Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. *Hum Mov Sci* 2016; 49: 1–8.

15. Rampinini E, Coutts AJ, Castagna C, Sassi R, Impellizzeri F. Variation in Top Level Soccer Match Performance. *Int J Sports Med* 2007; 28(12): 1018–1024.

16. Castellano J, Blanco-Villaseñor A, Álvarez D. Contextual Variables and Time-Motion Analysis in Soccer. *Int J Sports Med* 2011; 32(06): 415–421.

17. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 2003; 21(7): 519–528.

18. Andrzejewski M, Chmura J, Pluta B, Strzelczyk R, Kasprzak A. Analysis of Sprinting Activities of Professional Soccer Players. *J Strength Cond Res* 2013; 27(8): 2134–2140.

19. Lago-Peñas C. The Role of Situational Variables in Analysing Physical Performance in Soccer. *J Hum Kinet* 2012; 35(1): 89–95.

20. Malone S, Owen AL, Newton M, Mendes B, Collins KD, Gabbett TJ. The acute:chonic workload ratio in relation to injury risk in professional soccer. *J Sci Med Sport* 2017; 20(6): 561–565.

21. Martín-López Á, Mendes RS, Castillo-Rodríguez A. Internal and External Loads in Training Week Before the Competition in U19 High-Level Soccer Players. *J strength Cond Res* 2018; 1–7.

22. Malone JJ, Lovell R, Varley MC, Coutts AJ. Unpacking the Black Box: Applications and Considerations for Using GPS Devices in Sport. *Int J Sports Physiol Perform* 2017; 12(Suppl 2): 18–26.

23. Bolker BM, Brooks ME, Clark CJ, Geange SW, Poulsen JR, Stevens M, Henry H, White JS. Generalized linear mixed models: a practical guide for ecology and evolution. *Trends Ecol Evol* 2009; 24 (3): 127–135.

24. Winter B, Grawunder S. The phonetic profile of Korean formal and informal speech registers. *J Phon* 2012; 40 (6): 808–815.

25. Nakagawa S, Schielzeth H. A general and simple method for obtaining R 2 from generalized linear mixed-effects models. *Methods Ecol Evol* 2013; 4(2): 133–142.

26. Bates D, Mächler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models

Using lme4. *J Stat Softw* 2015; 67(1).
27. Guerrero-Calderón B. The effect of short-term and long-term coronavirus quarantine on physical performance and injury incidence in high-level soccer. *Soccer Soc* 2020; 1–11.
28. Castillo-Rodríguez A, Cano-Cáceres FJ, Figueiredo A, Fernández-García JC. Train Like You Compete? Physical and Physiological Responses on Semi-Professional Soccer Players. *Int J Environ Res Public Health* 2020; 17(3): 756.
29. Paul DJ, Bradley PS, Nassis GP. Factors Affecting Match Running Performance of Elite Soccer Players: Shedding Some Light on the Complexity. *Int J Sports Physiol Perform* 2015; 10(4): 516–519.
30. Grünbichler J, Federolf P, Gatterer H. Workload efficiency as a new tool to describe external and internal competitive match load of a professional soccer team: A descriptive study on the relationship between pre-game training loads and relative match load. *Eur J Sport Sci* 2019; 1–17.
31. Hader K, Rumpf MC, Hertzog M, Kilduff LP, Girard O, Silva JR. Monitoring the Athlete Match Response: Can External Load Variables Predict Post-match Acute and Residual Fatigue in Soccer? A Systematic Review with Meta-analysis. *Sport Med - Open* 2019; 5(1).
32. Hulin BT, Gabbett TJ, Lawson DW, Caputi P, Sampson JA. The acute: Chronic workload ratio predicts injury: High chronic workload may decrease injury risk in elite rugby league players. *Br J Sports Med* 2016; 50(4): 231–6.
33. Bowen L, Gross AS, Gimpel M, Li F-X. Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. *Br J Sports Med* 2017; 51(5): 452–459.
34. No M, Kwak H-B. Effects of environmental temperature on physiological responses during submaximal and maximal exercises in soccer players. *Integr Med Res* 2016; 5(3): 216–222.
35. Özgünen KT, Kurdak SS, Maughan RJ, Zeren Ç, Korkmaz S, Yazıcı, Z, Ersöz G, Shirreffs SM, Binnet, MS, Dvorak J. Effect of hot environmental conditions on physical activity patterns and temperature response of football players. *Scand J Med Sci Sports* 2010; 20(Suppl 3): 140–147.
36. Carling C. Influence of opposition team formation on physical and skill-related performance in a professional soccer team. Eur J Sport S*ci* 2011; 11(3): 155–164.

37. Baptista I, Johansen D, Figueiredo P, Rebelo A, Pettersen SA. A comparison of match-physical demands between different tactical systems: 1-4-5-1 vs 1-3-5-2. *PLoS One* 2019; 14(4): 1–4.
38. Hewitt A, Greenham G, Norton K. Game style in soccer: what is it and can we quantify it? *Int J Perform Anal Sport* 2016; 16(1): 355–372.
39. Lago-Peñas C. The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *J Sports Sci* 2009; 27(13): 1463–1469.
40. Yi Q, Gómez MA, Wang L, Huang G, Zhang H, Liu H. Technical and physical match performance of teams in the 2018 FIFA World Cup: Effects of two different playing styles. *J Sports Sci* 2019; 37(22): 2569–2577.

Estudio 4

The Effect of Short- and Long-term Coronavirus Quarantine on Physical Performance and Injury Incidence in High-level Soccer

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The Effect of Short- and Long-term Coronavirus Quarantine on Physical Performance and Injury Incidence in High-level Soccer

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Abstract

In 2020, the world is suffering an unprecedented pandemic (coronavirus or COVID-19) that it is eliciting devastating consequences. This article has gathered the opinions of international soccer experts about the short- and long-term effects of coronavirus quarantine on physical performance and injury incidence in high-level soccer players, by means of open-ended questions encouraging the expression of unrestricted opinions. In this way, the text aims to provide the reader with a compilation and comparison of knowledge from a practical perspective in order to understand how the coronavirus quarantine may affect the high-level players' physical performance from the extensive experience and broad career of conditioning area professionals in top-level soccer teams around the world together with the knowledge provided by research.

Keywords: COVID-19; training load; sport; monitoring; transition period

Contextualization

Coronavirus disease (COVID-19) has hit hard. In 2020, the world is experiencing an unprecedented and devastating situation for humans and for the economy worldwide[1]. In December of 2019, there was an unbreak of a severe respiratory deficiency caused by a new viral pathogen (SARS-CoV2) in Wuhan, Hubei Province, China[2]. The epidemic rapidly has extended over the country and then into the whole world, leading the World Health Organization (WHO) to declare a Public Health Emergency of International Concern[3]. With the aim of trying to halt this pandemic and supported by the WHO, governments around the world have been forced to activate a state of emergency by quarantine (QRT), bringing countries to a standstill, closing all types of services and shops (except for minimum services) and forcing all citizens to isolate themselves in their homes; from children to bakers, teachers and engineers, and consequently also elite athletes[4]. The coronavirus is expected to cause a major impact on professional soccer in all areas[5], causing billions of euros in losses from television, image and publicity rights, transfer markets, and affecting an already tight competition schedule. Given the great economic impact that soccer generates, all the institutions organizing the competitions (i.e. UEFA and the professional leagues of each country) have the firm intention of completing the rest of the current season. For instance, in Spain that would be 11 league matches and 5 or 6 more for teams competing in the UEFA Champions League or Europa League (depending on which stage the team reaches). Therefore, teams will be forced to compete every 3 days for several weeks in order to 'meet deadlines', all of which leads to an environment of physical, physiological and psychological stress for players[6]. This new and unexpected situation will present practitioners with a complex challenge in order to get players to compete in the best possible condition and minimize injury incidence.

The opinions of international soccer experts (Table 1) on the effect of short- (ST) and long-term (LT) QRT on physical performance and injury incidence in high-level soccer players have been gathered in this text, using open-ended questions in order to encourage the expression of unrestricted opinions. In this way, this letter aims to provide the reader, whether strength & conditioning coach (S&C), physiotherapist, children's coach or sport enthusiastic, from a practical perspective with a compilation and relationship of knowledge to understand how the coronavirus quarantine may affect the physical performance of high-level players based on the extensive experience and broad careers of conditioning area professionals in top-level soccer teams around the world together with the knowledge provided by research.

Tabla 11. Estudio 4 – [Table 1. Experts participating in the study. (S&C, strength & conditioning coach; ex, previous jobs)].

Experts	Employment	Professional Career
Ángel Aceña	S&C Coach	Ex S&C: Sevilla FC, Costa Rica National Team (Russia World Cup 2018), Vitesse, Qatar SC, Zambia National Team (Africa Cup 2019)
Dr. Miguel Ángel Campos	S&C Coach Cádiz CF (Spain)	PhD Sport Sciences, Lecturer ISSPF®, Associate professor of soccer (University Pablo de Olavide, Sevilla). Ex S&C: Almería CF, Argelia National Team.
Dr. Sergio Jiménez Rubio	Sports therapist Getafe CF (Spain)	PhD Sport Sciences, Physiotherapist. Ex: Valladolid CF
Paulino Granero	S&C Coach CSKA Moscow (Russia) & Russia National Team	Ex S&C: Betis CF
Lluis Sala Pérez	S&C Coach & Sports therapist FC Girondix Bordeaux (France)	PhD Sport Sciences, MSc Sports Performance, Professor of Master Sports Performance (University of Girona) Ex S&C: Girona FC.
Dr. Nacho Torreño	Head of Performance & Methodology FC Basel (Switzerland)	PhD Sport Sciences, Coach UEFA-A. Ex (10 years as Paulo Sousa's 2nd coach): Tianjin Quanjian (China), ACF Fiorentina (Italy), FC Basel (Switzerland) Maccabi Tel Aviv (Israel) y Videoton FC (Hungary).
Dr. Léo Djaoui	S&C Coach & Head of Performance SC Amiens (France)	PhD Sport Sciences, Ex PF: Union SG (Belgium), Pafos FC (Cyprus)
Dr. Adam Owen	Head Coach / Head of Performance	PhD Sport Sciences, Coach UEFA Pro, Ex S&C: Wales National Team, Head of Performance: Hebei China Fortune FC; Head Coach: SK Lechia Gdansk, Rangers FC, Celtic FC; Assistant Coach. Sheffield United FC, Sheffield Wednesday FC-

Before starting, it would be appropriate to contextualize the new situation with regard to professional soccer by sharing a reflection from Dr. Torreño[7]:

"We are faced up with a totally new and unknown situation. Uncertainty is one of the main characteristics in soccer, and the more dynamic, complex, diverse and hostile the environment, the greater the uncertainty we face. Our future decision-taking or actions will depend on the interaction with the context we find ourselves in. In any case, I do not believe we have the answers to all the questions we can ask. In addition, I do not think we can even imagine what will happen in the next few weeks or months. Supporting us in the research, our work experience and common sense will be the key to reducing the negative impact of this QRT on our players."

Effect on physical performance

Due to the forecast of a congested competition calendar after QRT, it will be necessary to optimize players' physical performance to withstand the high physical demands of high-level soccer[8]. However, it is known that the suspension of training negatively affects physical performance and increases the injury risk factors (RF) in the first weeks of training after the transitory period[9]. It is expected between 45 to 60 days from the last training session performed and the first session once the QRT is over, although it cannot be exactly known as this depends on the progress of the pandemic. Therefore, it will be practically the same time period as preseason, but happening in the middle of the competitive period. The experts reported that individualized home training programs (HTP) have been developed for all players during QRT, in addition to specific nutrition plans[10]. Nonetheless, despite the fact that all players are expected to act professionally and perform their HTPs, coinciding with the research, experts consider that there will be an irremediable physical performance decrease in the ST and, consequently, an increase in RFs[11]. These authors explained that periods of detraining lead to negative changes in body composition; a decrease in muscle power, especially in the ability to produce force in changes of direction (CODs) and multiarticular dynamic actions; and a reduction of maximum oxygen consumption (VO2max) and recovery time[12]. The experts considered that the QRT will lead to negative changes in body composition in ST (Torreño & Owen)[13], decrease in cardiorespiratory capacity of players (Aceña) [14] and decrease in the capacity to generate strength, especially in soccer-specific muscle contractions and effort (Campos, Jiménez Rubio & Djaoui) [15]. It should be noted that these structural mismatches generated in transition periods negatively affect the tolerance to high training volumes and intensities during the first weeks back in training[16].

Body composition

Keeping a proper body composition is very important for optimizing the players' physical performance and reducing RF[17]. In addition, these authors found a lower body-fat percentage and higher percentage of muscle mass in young soccer players from successful teams[18]. Although there are individual differences in ideal player body composition depending on the playing style and the physiological profile of each player, an adequate percentage of body fat for professional soccer players is between 10-12%[19].

Cardiorespiratory capacity

Some studies have shown a VO2max decrease of 3.5 to 6.1% after 4-week transition period[20] and even 10.7% with only 2 weeks off-training[21]. In the same line, other authors found a heart rate (HR) increase at different running-speed ranges, thus affecting the internal:external workload ratio when players returned to training[22]. Sotiropoulus[23] concluded that conducting training programs during a 4-week transition period does not prevent the VO2max decrease, but assists in minimizing that decrement. On the other hand, other authors maintained that the decrease in cardiorespiratory capacity can be prevented by means of high-intensity training[24]. These authors concluded that one high-intensity training (HIT) session per week was effective in preventing the VO2max decrease in professional soccer players[25]. In the same line, Dr. Campos[26] argues that although players undergo a detraining process, the physiological losses (i.e. VO2max, ventilatory thresholds or body composition) may not be very high if players have correctly developed the HTPs.

Muscle disorders

Strength and power training are very important in order to maintain the essential aspects of intra- and intermuscular coordination in the soccer-specific motor patterns during QRT[27]. For developing a broad spectrum of speed-strength in the transition period, combining exercises of strength-endurance, plyometrics and specific-strength efforts like accelerations, decelerations or CODs are recommended[28], in addition to multiarticular exercises such as the squat[29]. Interestingly, some authors showed that a single weekly strength training of squats was enough to maintain an adequate level of strength, jumping and sprinting during the transition period in professional soccer players[30]. Although the aforementioned studies analysed the transition period between seasons, and QRT has occurred in the middle of competitive period, the expert Lluis Sala[31] is in line with these authors and considers that an appropriate HTP that provides players with a big variability of muscle tension through a wide variety of exercises, different muscle contractions and varying the speed of execution, the power loss may be considerably minimized or even maintained at similar levels. Besides, eccentric training should be also performed during QRT with the aim of decreasing the muscle damage (high creatine-kinase [CK] concentration) that occurs when retraining[32]. However, Dr.

Djaoui[33] believes that many players will not be able to produce stimuli high enough for their level either for performance purposes, prevention or injury recovery.

Locomotion activities

Based on the study of Silva[34], Dr. Torreño[35] considers that muscle disorders generated during QRT will affect to the most determinant activities in soccer as high-intensity actions or those with high neuromuscular load such as the repeat-sprint ability (RSA) or CODs. Running at maximum or sub-maximum speed is one of the most important activities in soccer and the experts agreed that it is one of the most affected (Jiménez Rubio, Granero, Sala, Torreño, Owen & Djaoui) [36]. In addition, Lluis Sala[37] also believes that there will be a decrease in the capacity to generate maximum speed peaks. In this sense, special caution should be taken to monitor and quantify this parameter, and analyse it relative to individual players' capacity because during the specific soccer activity (e.g. during a match), the slowest players reach their maximum speed (100%) repeatedly, while the fastest players often do not need to reach more than 85-94% of their maximum speed to succeed the action[38]. Other parameters that will be affected are the accelerations and decelerations (Jiménez Rubio & Djaoui) [39], the recovery capacity between high-intensity efforts (Granero)[40] or the time spent to reach a high fatigue state (Granero) [41].

Apart from all parameters that may be affected, the main problem of HTPs during QRT is the decontextualization of exercises (Jiménez Rubio, Granero, Sala, Djaoui & Campos)[42]. Although there are players who have been able to carry out different running activities, CODs, jumps or sprints, soccer is an interactive sport played with a ball in which there are also collisions, disputes, passes, jumps with opposition, etc. generating a high level of uncertainty[43] and cannot be simulated with HTPs. In this sense, the players' capacity to generate power in different situations of contact with an opponent such as fighting or aerial disputes will be affected (Sala) [44]. Finally, Drs. Djaoui & Campos[45] believe that the most affected variable for players is the capacity to be efficient in the complex activity of soccer because the HTPs cannot simulate the specific situations of soccer; multi-component tasks, multi-directional movements, information input, decision making or ball handling, among others.

Injury incidence

A recent systematic review established an injury incidence in adult professional soccer players of 2.5 to 9.4 per 1000 hours, with higher number of injuries occurring during matches[46]. In accordance with Pfirrmann, all experts agree that muscle injuries will be the most affected[47] (Table 2). In this regard, a study conducted with elite European teams during 7 consecutive seasons showed that the thigh was the most common location (17% of total injuries), with hamstring strain representing the highest incidence (12%) compared to 5% of quadriceps[48]. Dr. Owen believes that most injuries will occur on reactive actions during turns[49]. For Dr. Torreño, the main RF will be the loss of muscle mass and strength[50].

In line with Ekstrand, Lluis Sala believes that different injuries will occur when the team returns to training and when competition begins[51]. As soon as the teams resume training, the flexor and adductor hip injuries commonly occurring the preseason, in addition with overuse injuries such as tendinopathy and groin pain will be the main types of injuries as a result of the scarcity of ball hitting during QRT[52]. On the other hand, due to the congested match schedule, teams will increase the incidence rate of muscle injuries once competition starts, without betting on a specific area. Based on the research, the author believes overuse injuries RF on adductor muscles and groin pain will be high from the second or third week onwards if there is not enough preparation time to progressively increase the load before the start of competition[53]. Ekstrand[54] found that adductors injuries accounted for 9% of total injuries (the seconds most common) and the incidence rate was greater during the preseason, i.e. after returning from a prolonged period of inactivity. Besides, since players generally will not have been able to perform adequate running and HIT with a high number of CODs and turns, along with the lack of ball-hitting training, the RF of groin pain from overloading will be increased[55]. Therefore, following the recommendations retrieved from the systematic review by these authors, it would be recommendable to assess the range of motion (ROM) of the hip joint in both adduction and abduction, together with possible deficits in muscle function after returning from QRT.

Tabla 12. Estudio 4 – [Table 2. Most recurrent injuries according to experts].

Injury/Location	Experts
Muscle – Hamstrings	Aceña, Campos, Sala, Torreño, Owen
Muscle – Quadriceps	Aceña, Campos, Jiménez Rubio, Sala, Torreño, Owen
Muscle – Adductors	Campos, Sala, Owen
Muscle – Calf	Jiménez Rubio, Owen
Groin pain	Sala
Tendinopathies	Sala
Joints	Granero
Hernias	Owen

Similarly, Ángel Aceña suggests two possible scenarios that might change the injury epidemiology: if the team does not have enough preparation time before returning to competition, added to the forecast of a congested match schedule, the most frequent injuries will be the hamstring strains; if, on the contrary, the teams can provide 3-4 weeks of preparation, the excessive training load that practitioners might program in order to quickly restore players' pre-QRT fitness will cause a greater number of quadriceps injuries[56].

Despite the need to quickly improve physical performance, all experts were in agreement about providing a minimum period of preparation of 3-4 weeks before restoring competition with the aim of progressively increasing the workload to withstand the match demands and thus avoid rapid training-load increases that might augment the RF[57]. In fact, Gabbett[58] maintains that week-to-week load increases should not exceed 10%. In this sense, for Dr. Owen there will be an increase in the number of overuse injuries or even hernias after 2-3 weeks if the preparation period is limited[59]. On the other hand, in order to stabilize the workload ratio (i.e. ratio of acute to chronic load), Aceña supports that double-match weeks should not start until the fourth or fifth week[60]. Research exists showing that a recovery period of 72 to 96 hours between matches is sufficient to maintain an appropriate fitness level, but it is not to maintain a low injury rate[61]. An accurately individualized training- and match-load management will be of paramount importance when returning to training after QRT[62]. Several experts agreed that there is a need for in-depth knowledge and exhaustive and individualized daily monitoring of players to adapt training and match load in order to identify the players best prepared for competition (Torreño, Jiménez Rubio, Granero, Sala & Djaoui)[63]. The use of all technological devices such as HR monitors, GPS, subjective scales, magnetometers, goniometers, force platforms, thermographic cameras, tensiomyography, blood, saliva and urine tests or sleep analysers may provide very useful information for analysing how players respond to imposed loads. For Aceña & Dr. Torreño the biggest challenge for teams will not be to restore fitness capacity, but to cope with a very congested match calendar which will complicate players' recovery process[64]. Dr. Torreño concluded; "the players will spend more time recovering than training", and therefore load individualization will be decisive[65]. Consequently, the control and dosage of minutes of play together with rotation of players will be key elements in load management for S&C Coaches (Aceña, Campos, Owen & Granero)[66], especially for teams also competing at international level, e.g. UEFA Champions League or Europa League (Jiménez Rubio)[67]. For Lluis Sala, the players' subjective perception of physical and psychological state and also the perception from technical staff should have an important role when deciding which players are better prepared to compete[68]. Nonetheless, in order to facilitate the management and dosage of minutes of play and to copes with the high density of matches schedules with lower risks, it might be interesting to exceptionally change the internal rules of competition with the aim of performing a greater number of substitutions during the match.

Physical performance & injury risk relationship

Figure 1 shows a subjective interpretation of the relationship between physical performance, workload bearing capacity and injury risk, differentiating the periods before QRT (pre-IR) and when retraining after QRT (post-IR). At first, it is important to note that a greater workload does not necessarily means better physical performance. However, it is well known that high-level soccer requires excellent physical capacity of players in order to cope with the demands of competition[69]. Therefore, players with good fitness (represented by the PP line) will be able to withstand very high loads with lower risk of injury. When the workload is increased to improve physical performance, there is a 'relative point' of load, which currently cannot be known since there are many contributing factors such as accumulated load[70], locomotion activity and intensity[71], mood and sleep quality[72], previous fatigue[73] or contextual factors[74], among others, in which there is an exponential increase in injury. In addition, rapid or excessive load increases may involve a substantially increased RF. Therefore, the training-free period of QRT will cause a deficit (represented by the grey shaded area) of the capacity to cope with greater loads[75] and increase the RF (represented by the left yield RF curve shift [post-RF]). A progressive load increase will help players to attain greater capacity to cope with the workload thus reducing load deficit caused by QRT and consequently improving the physical performance and decreasing the injury RF (flattening and right-shift of the curve, from post-IR to pre-IR). To minimize the left-shift of the curve and therefore produce a smaller load deficit that players are able to cope without an exponential increase in RF, players should maintain an adequate strength capacity during QRT, mainly in the lower limbs, to mitigate the muscle damage that will occur when they return to training (Torreño)[76].

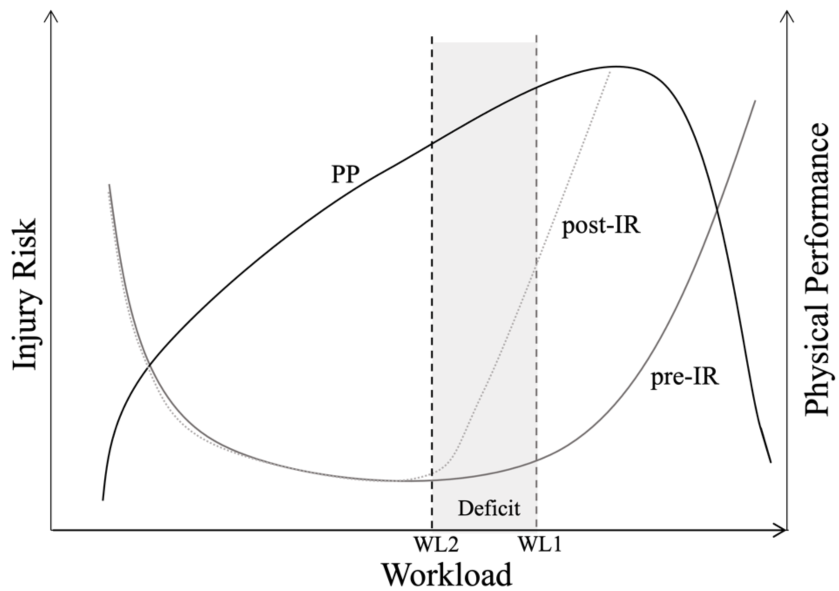

Figura 10. Estudio 4 – [Figure 1. Subjective representation of the relationship between physical performance (PP), workload bearing capacity and injury risks before (pre-IR) and after (post-IR) quarantine. (WL1: maximum PP without an exponential IR increase before quarantine; WL2: maximum PP without an exponential IR increase when players return to training after quarantine)].

Return to training

There are several opinions regarding the starting point after QRT. Dr. Owen proposes an initial workload about 50-60%, although it may vary depending of the available preparation time before competition[77]. Djaoui, Jiménez Rubio & Sala consider that players' physical capacity should be tested as soon as training resumes[78]. For Aceña, resumption of training will be a challenge for S&C coaches since there is not recent GPS data for players that allow them to make decisions about increasing or decreasing the load[79]. It would be inappropriate and inaccurate to use previous player data such as accumulated load or acute:chronic workload ratio[80]. Therefore, Aceña proposes the 'minimum dose of effective training-load' as the starting point, and from there builds a progressive adaptation to gradually restore the conditional records previous to QRT without increasing RF (Aceña & Jiménez Rubio)[81]. In this sense, players should gain the maximum time by performing progressive HTPs before the end of QRT with the aim of attaining a minimum level of strength and running endurance, thus avoiding loss of training days with the team or an increase in the RF after QRT (Djaoui & Campos)[82].

On the other hand, as a result of the short preparation period available, the disruption of technical-tactical performance and game pace (Djaoui, Jiménez Rubio, Campos & Granero)[83], and the need to attain performance quickly due to the forecast proximity of competition, group training sessions after QRT should be completely contextualized with respect to the game from the beginning by integrating the conditional goals into the tasks to improve game pace (Torreño & Campos)[84]. Therefore, in addition to improving players' physical performance by generating new and game-specific muscle adaptations, the injury RF will be reduced and recovery process will improve due to the positive relationship between players' capacity to generate strength and the reduction of post-match muscle damage markers[85]. However, supported by several experts, players should undertake individualized training sessions that complement the team training in order to enhance possible weaknesses and facilitate the recovery processes[86]. What appears obvious is the need for collaboration and support from all the members of team, both players and coaching staff, in order to deal with this situation (Sala)[87]. In addition, maintaining a continuous communication with the medical service will be necessary in order to exchange as much information as possible about the physical state of players (Granero & Sala)[88].

Long-term effects

There are many doubts about how the QRT will affect LT (Jiménez Rubio, Granero, Sala, Torreño & Djaoui)[89]. For Dr. Jiménez Rubio, the current focus is on assessing how the QRT period has affected players in order to design the applicable individualized training programs for preventing ST injuries[90]. Afterwards, different training contexts may be handled to prevent LT injuries. Dr. Djaoui believes that the LT injury incidence will no increase because players will have a normal transition period between seasons for recovering and will be able to perform a proper preseason[91]. The only LT injury RF Dr. Djaoui considers is that the player is injured during the early phases of QRT, as the performance drop will be coupled with the need for injury-specific training[92].

Finally, the players psychological state will be of paramount importance (Granero, Djaoui & Jiménez Rubio)[93]. The resumption will occur over a key season period in which the ranking classification is defined: relegations, classification for international competitions, or winning or losing a championship. The given match outcomes and the uncertainty of how it will affect their futures will place great pressure on players and might cause an increase in injury incidence (Granero & Torreño)[94].

Conclusions

The aim of this paper was to gather the opinion of international experts about how the coronavirus QRT will affect the short- and long-term physical performance of high-level soccer players. All the participating experts were in agreement that players will return to training with a reduced physical capacity. Due to the proximity of competition, players will be required to optimize their physical performance quickly and it will negatively impact injury incidence. Hamstring and quadriceps strains will be the most common injuries in addition to overuse injuries in adductor muscles and groin pain which may also have a high injury rate if there are rapid load increases. Therefore, the development of an appropriate HTP will be a key aspect in order to 'save time' before resumption of training and prevent injuries. These HTPs should focus mainly on HIT, and strength and power training. In addition, eccentric training must be included in the strength program in order to reduce muscle damage when the team sessions start. However, the decontextualization of training during QRT will be the main problem and therefore a negative affectation on technical-tactical performance and game pace is also expected. Therefore, in order to protect players and avoid a considerable increase in the injury rate, all experts were in agreement with allowing a minimum period of preparation of 3-4 weeks before restoring competition in order to progressively increase the workload. In addition, it will be necessary to dose the minutes of play for each player and carry out timely substitutions. In this sense, it might be interesting to be able to exceptionally perform a greater number of substitutions during the match. Finally, the congested match period, the given match outcomes and the uncertainty of how it will affect their futures will put great pressure and stress on players and might cause an increase in injury incidence.

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Notes

1 World Health Organization, ‘Coronavirus report’.
2 Ibid.
3 Rodríguez-Morales et al. ‘Going-Travel and the 2019 novel coronavirus’.
4 See note 1 above.
5 Corsini et al., ‘Football cannot restart soon’.
6 Dupont et al., ‘Effect of 2 matches.’
7 Personal commentary from Dr. Torreño.
8 Bradley et al., ‘Tier-specific evolution’.
9 Silva et al., ‘The transition period in soccer’.
10 Overall opinion of all experts.
11 See note 9 above.
12 Ibid.
13 Joint opinion from Torreño & Owen.
14 Aceña, personal opinion.
15 Joint opinion from Campos, Jiménez Rubio & Djaoui.
16 See note 9 above.
17 Lago-Peñas et al., ‘'Anthropometric and physiological characteristics of young soccer players’.
18 Ibid.
19 Owen et al., ‘Heart Rate–Based Training Intensity’.
20 Sotiropoulos et al., ‘The Effect of a 4-Week Training Regimen’.
21 Christensen et al., ‘VO2 kinetics and performance in soccer players.’

22 Mohr, Krustrup and Bangsbo, 'Fatigue in soccer'
23 See note 20 above.
24 Slettaløkken and Rønnestad, 'High-Intensity Interval Training Every Second Week'.
25 Ibid.
26 Campos, personal opinion.
27 See note 9 above.
28 Silva, Nassis, and Rebelo, 'Strength training in soccer'
29 See note 9 above.
30 Rønnestad, Nymark & Raastad, 'Effects of in-season strength maintenance training frequency'
31 Sala, personal opinion.
32 See note 9 above.
33 Djaoui, personal opinion.
34 See note 9 above.
35 Torreño, personal opinion.
36 Joint opinion from Jiménez Rubio, Granero, Sala, Torreño, Owen & Djaoui.
37 Sala, personal opinion.
38 Al Haddad et al., 'Peak match speed and maximal sprinting speed'.
39 Joint opinion from Jiménez Rubio & Djaoui.
40 Granero, personal opinion.
41 Ibid
42 Joint opinion from Jiménez Rubio, Granero, Sala, Djaoui & Campos.
43 Sarmento et al., 'What Performance Analysts Need to Know'.
44 Sala, personal opinion.
45 Joint opinion from Djaoui & Campos.
46 Pfirrmann et al., 'Analysis of injury incidences.'
47 Overall opinion of all experts.
48 Ekstrand, Hägglund, and Waldén, 'Injury incidence and injury patterns in professional football'.
49 Owen, personal opinion.
50 Torreño, personal opinion.
51 Sala, personal opinion.
52 Ibid.
53 Ibid.
54 See note 48 above.
55 Kloskowska et al., 'Movement Patterns and Muscular Function'.
56 Aceña, personal opinion.
57 Overall opinion of all experts.
58 Gabbet, 'The training—injury prevention paradox'.
59 Owen, personal opinion.
60 Aceña, personal opinion.
61 See note 6 above.
62 Suarez-Arrones et al., 'Match-play activity profile'.
63 Joint opinion from Torreño, Jiménez Rubio, Granero, Sala & Djaoui.
64 Join opinion from Aceña & Torreño.
65 Torreño, personal opinion.
66 Joint opinion from Aceña, Campos, Owen & Granero.
67 Jiménez Rubio, personal opinion.
68 Sala, personal opinion.
69 See note 8 above.
70 Malone et al., 'High-speed running and sprinting'.
71 Martín-García et al., 'Quantification of a professional football team's external load'.
72 Carling et al., 'Monitoring of Post-match Fatigue'.
73 Bradley and Noakes, 'Match running performance fluctuations in elite soccer'.
74 Rago et al., 'Contextual Variables and Training Load Throughout a Competitive Period'.
75 See note 58 above.
76 Torreño, personal opinion.
77 Owen, personal opinion.
78 Joint opinion from Djaoui, Jiménez Rubio & Sala.
79 Aceña, personal opinion.
80 Bowen et al., 'Accumulated workloads and the acute:chronic workload ratio'.

[81] Joint opinion from Aceña & Jiménez Rubio.
[82] Joint opinion from Djaoui & Campos.
[83] Joint opinion from Djaoui, Jiménez Rubio, Campos & Granero.
[84] Joint opinion from Torreño & Campos.
[85] Akenhead and Nassis, 'Training Load and Player Monitoring in High-Level Football'.
[86] Joint opinion from Granero, Torreño, Jiménez Rubio & Campos.
[87] Sala, personal opinion.
[88] Joint opinion from Granero & Sala.
[89] Joint opinion from Jiménez Rubio, Granero, Sala, Torreño & Djaoui.
[90] Jiménez Rubio, personal opinion.
[91] Djaoui, personal opinion.
[92] Ibid.
[93] Joint opinion from Granero, Djaoui & Jiménez Rubio.
[94] Joint opinion from Granero & Torreño.

References

Akenhead R. and G.P. Nassis. 'Training Load and Player Monitoring in High-Level Football: Current Practice and Perceptions.' *International Journal of Sports Physiologhy & Performance*. 11, no. 5 (2016): 587-593. doi:10.1123/ijspp.2015-0331

Bowen L., A.S. Gross, M. Gimpel and F-X. Li. 'Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players.' *British Journal of Sports Medicine* 51, no. 5 (2017): 452-459. doi:10.1136/bjsports-2015-095820

Bradley P.S., D.T. Archer, B. Hogg, G. Schuth, M. Bush, C. Carling and C. Barnes. 'Tier-specific evolution of match performance characteristics in the English Premier League: it's getting tougher at the top.' *Journal of Sports Sciences* 34, no. 10: (2016): 980-987. doi:10.1080/02640414.2015.1082614

Bradley P.S. and T.D. Noakes. 'Match running performance fluctuations in elite soccer: Indicative of fatigue, pacing or situational influences?' *Journal of Sports Sciences* 31, no. 15 (2013): 1627-1638. doi:10.1080/02640414.2013.796062

Carling C., M. Lacome, A. McCall, G. Dupont, F. Le Gall, B. Simpson and M. Buchheit. 'Monitoring of Post-match Fatigue in Professional Soccer: Welcome to the Real World.' *Sport Medicine* 48, no. 12 (2018): 2695-2702. doi:10.1007/s40279-018-0935-z

Christensen P.M., P. Krustrup, T.P. Gunnarsson, K. Kiilerich, L. Nybo and J. Bangsbo. 'VO2 kinetics and performance in soccer players after intense training and inactivity.' *Medicine & Sciences in Sports Exercise* 43, no. 9 (2011): 1716-1724. doi:10.1249/MSS.0b013e318211c01a

Corsini A., G.N. Bisciotti, C. Eirale and P. Volpi. 'Football cannot restart soon during the COVID-19 emergency! A critical perspective from the Italian experience and a call for action.' *British Journal of Sports Medicine* 17, no 5 (2020): 2020-102306. doi:10.1136/bjsports-2020-102306

Dupont G., M. Nedelec, A. McCall, D. McCormack, S. Berthoin and U. Wisløff. 'Effect of 2 soccer matches in a week on physical performance and injury rate.' *American Journal of Sports Medicine* 39, no.9 (2010): 1752-1758. doi:10.1177/0363546510361236

Ekstrand J., M. Hägglund and M. Waldén. 'Injury incidence and injury patterns in professional football: The UEFA injury study.' *British Journal of Sports Medicine* 45, no. 7 (2011): 553-558. doi:10.1136/bjsm.2009.060582

Gabbett T.J. 'The training—injury prevention paradox: should athletes be training smarter and harder?' *British Journal of Sports Medicine* 50, no.5 (2016): 273-280. doi:10.1136/bjsports-2015-095788

Al Haddad H., B.M. Simpson, M. Buchheit, V. Di Salvo and A. Mendez-Villanueva. 'Peak match speed and maximal sprinting speed in young soccer players: Effect of age and playing position.' *International Journal of Sports Physiologhy & Performance* 10, no. 7 (2015): 888-896. doi:10.1123/ijspp.2014-0539

Kloskowska P., D. Morrissey, C. Small, P. Malliaras and C. Barton. 'Movement Patterns and Muscular Function Before and After Onset of Sports-Related Groin Pain: A Systematic Review with Meta-analysis.' *Sport Medicine* 1, no. 21 (2016). doi:10.1007/s40279-016-0523-z

Lago-Peñas C., L. Casais, A. Dellal, E. Rey and E. Domínguez. 'Anthropometric and physiological characteristics of young soccer players according to their playing positions: relevance for competition success.' *Journal of Strength & Conditioning Research* 25, no. 12 (2011): 3358-3367. doi:10.1519/JSC.0b013e318216305d

Malone S., A.L. Owen, B. Mendes, B. Hughes, K. Collins and T.J. Gabbett. 'High-speed running and sprinting as an injury risk factor in soccer: Can well-developed physical qualities reduce the risk?' *Journal of Science & Medicine in Sport* 21, no. 3 (2017): 257-262. doi:10.1016/j.jsams.2017.05.016

Martín-García A., A. Gómez Díaz, P.S. Bradley, F. Morera and D. Casamichana. Quantification of a professional football team's external load using a microcycle structure. *Journal of Strength & Conditioning Research* 32, no. 12 (2018): 3511-

3518. doi:10.1519/jsc.0000000000002816

Mohr M., P. Krustrup and J. Bangsbo. 'Fatigue in soccer: A brief review.' *Journal of Sports Sciences* 23, no. 6 (2005): 593-599. doi:10.1080/02640410400021286.

Owen A.L., J.J. Forsyth, D.P. Wong, A. Dellal, S.P. Connelly and K. Chamari. 'Heart Rate–Based Training Intensity and Its Impact on Injury Incidence Among Elite-Level Professional Soccer Players.' *Journal of Strength & Conditioning Research* 29, no. 6 (2015): 1705-1712. doi:10.1519/JSC.0000000000000810 https://doi.org/10.1519/JSC.0000000000000810.

Pfirrmann D., M. Herbst, P. Ingelfinger, P. Simon and S. Tug. 'Analysis of injury incidences in male professional adult and elite youth soccer players: A systematic review.' *Journal of Athletic Training* 51, no. 5 (2016): 410-424. doi:10.4085/1062-6050-51.6.03

Rago V., A. Rebelo, P. Krustrup and M. Mohr. 'Contextual Variables and Training Load Throughout a Competitive Period in a Top-Level Male Soccer Team.' *Journal of Strength & Conditioning Research* 1, no. 25 (2019). doi:10.1519/jsc.0000000000003258

Rodríguez-Morales A.J., K. MacGregor, S. Kanagarajah, D. Patel and P. Schlagenhauf. 'Going global – Travel and the 2019 novel coronavirus.' *Travel Medicine & Infectious Disease* 33 (2020). doi:10.1016/j.tmaid.2020.101578

Rønnestad B.R., B.S. Nymark and T. Raastad. 'Effects of In-Season Strength Maintenance Training Frequency in Professional Soccer Players.' *Journal of Strength & Conditioning Research* 25, no.10 (2011): 2653-2660. doi:10.1519/JSC.0b013e31822dcd96

Sarmento H., F.M. Clemente, D. Araújo, K. Davids, A. McRobert and A. Figueiredo. 'What Performance Analysts Need to Know About Research Trends in Association Football (2012–2016): A Systematic Review.' *Sport Medicine* (2017): 1-38. doi:10.1007/s40279-017-0836-6

Silva J.R., J. Brito, R. Akenhead and G.P. Nassis. 'The Transition Period in Soccer: A Window of Opportunity'. *Sport Medicine* 46, no. 3 (2016): 305-313. doi:10.1007/s40279-015-0419-3

Silva J.R., G.P. Nassis and A. Rebelo. 'Strength training in soccer with a specific focus on highly trained players.' *Sport Medicine* 1, no.1 (2015): 17. doi:10.1186/s40798-015-0006-z

Slettaløkken G. and B.R. Rønnestad. 'High-Intensity Interval Training Every Second Week Maintains VO2max in Soccer Players During Off-Season.' *Journal of Strength & Conditioning Research* 28, no.7 (2014): 1946-1951. doi:10.1519/JSC.0000000000000356

Sotiropoulos A., A.K. Travlos, I. Gissis, A.G. Souglis and A. Grezios. 'The Effect of a 4-Week Training Regimen on Body Fat and Aerobic Capacity of Professional Soccer Players During The Transition Period.' *Journal of Strength & Conditioning Research* 23, no. 6 (2009):1697-1703. doi:10.1519/JSC.0b013e3181b3df69

Suarez-Arrones L., N. Torreño, B. Requena, E. Sáez De Villarreal, D. Casamichana, J.C. Barbero-Alvarez and D. Munguía-Izquierdo. 'Match-play activity profile in professional soccer players during official games and the relationship between external and internal load.' *The Journal of Sports Medicine and Physical Fitness* 55, no. 12 (2015):1417-1422. http://www.ncbi.nlm.nih.gov/pubmed/25289717.

World Health Organization. '*Coronavirus Situation Report 105.' (2020)* doi:10.1001/jama.2020.2633.

XI. Conclusiones

Conclusiones

I. La conclusión principal de esta Tesis Doctoral se sustenta en la existencia de una alta variabilidad en las respuestas físicas de futbolistas profesionales compitiendo en las categorías de Primera, Segunda y Segunda División 'B' del fútbol español por posición de juego y considerando diversos factores contextuales (p.ej., periodo de la temporada o calidad del oponente). Por tanto, se pone de manifiesto la importancia de contextualizar la carga que realizan los jugadores a un escenario específico, destacando además la necesidad de realizar una TL adecuada durante el microciclo para obtener posteriormente un mejor rendimiento físico en el partido próximo.

II. Los factores contextuales afectan al rendimiento físico de futbolistas profesionales. Además de la posición de juego y el día de entrenamiento respecto al partido, la localización donde se juegue el partido (en casa o fuera), el periodo de la temporada y la calidad del equipo rival al que tenga que enfrentarse, aparte de influir en las respuestas físicas de los futbolistas en el partido, también tiene efecto en las respuestas físicas mostradas por los jugadores en las diferentes sesiones de entrenamiento realizadas en el microciclo semanal previo al partido en cuestión. Por tanto, los factores contextuales deben considerarse dentro de la programación de la carga de entrenamiento de los futbolistas (estudios 1 y 3).

III. Se establecen modelos de predicción de las respuestas físicas de los futbolistas en entrenamiento considerando los factores contextuales: periodo de la temporada, día de entrenamiento, localización, calidad del equipo rival y posición de juego (estudio 1).

IV. Existe una modificación del comportamiento físico de los futbolistas tras la destitución del entrenador a mediados de temporada. En entrenamiento, se produce un descenso de las respuestas físicas con la llegada del nuevo entrenador, mientras que se mantiene un rendimiento similar en competición con ambos entrenadores (estudio 2).

V. Se puede predecir las respuestas físicas de los futbolistas en partido (TotalD, HIRD y SPD) a partir de la carga realizada durante la semana de entrenamiento previa. En este sentido, la TotalD recorrida en la semana de entrenamiento tiene en efecto negativo en el rendimiento mostrado en partido, mientras que la HIRD tiene un efecto positivo (estudio 3).

VI. Todos los expertos coincidieron en que los futbolistas de élite mostrarían menor capacidad física en la vuelta a la actividad tras el periodo de cuarentena por coronavirus. Realizar una periodización y programación de la carga óptima cuando retome la competición es de vital importancia para evitar un incremento elevado de la incidencia de lesiones. En este sentido, las lesiones musculares de isquiosurales y cuádriceps, además de lesiones por sobreuso en aductores y pubalgias, son las que contarán con mayor incidencia (estudio 4).

XII. Conclusions

Conclusions

I. The main conclusion of this Doctoral Thesis is the high variability of physical responses in professional soccer players competing in the Spanish First, Second and Second B division by playing position and considering several contextual factors (e.g., season period or opponent quality). Therefore, the importance of contextualizing the load to a specific scenario is evidenced, highlighting the need to perform an appropriate TL throughout the microcycle to subsequently obtain a better physical performance in the upcoming match.

II. Contextual factors affect the physical performance of professional soccer players. Besides to the playing position and the training day relative to the match, de location of the match (home or away), the season period and the quality of the opponent to face with, in addition to affecting the players' physical responses in the match, also affect the physical responses in the training sessions performed in the weekly microcycle before the corresponding match. Therefore, contextual factors should be considered within the training load programming of soccer players (study 1 and 3).

III. Prediction models of the players' physical responses in training considering the effect of the contextual factors season period, training day, match location, opponent quality and playing position have been established (study 1).

IV. Professional players show different physical behaviour after a mid-season coach turnover. There is a decrease in the physical responses with the new coach in training, while performance is similar with both coaches in competition (study 2).

V. The players' physical responses in the match (TotalD, HIRD and SPD) can be predicted from the workload performed during the training week before. Thus, the TotalD covered during the previous training week negatively affects physical performance in the match, while the HSRD has a positive effect (study 3).

VI. All experts agreed that top-level soccer players would show lower physical capacity when they have to return to training and competition after the coronavirus lockdown. Developing optimal periodization and programming of workload when the competition returns is paramount to avoid a high injury incidence. Accordingly, hamstring and quadriceps strains, in addition to overuse injuries on adductors will be the most prevalent injuries (study 4).

XIII. Aplicaciones Prácticas

Aplicaciones Prácticas

Un punto fundamental de esta Tesis Doctoral y por ende de cada uno de los artículos publicados es proporcionar aplicaciones prácticas para que entrenadores y preparadores físicos pueden utilizar con sus equipos.

I. En el estudio 1 se propone un nuevo e innovador enfoque para la cuantificación y monitorización de la carga de entrenamiento en el fútbol basado en modelos de predicción de las respuestas físicas considerando diferentes factores contextuales como la localización del partido, periodo de la temporada, día de entrenamiento, localización, calidad del equipo rival y posición de juego. Estos modelos pueden ser utilizados por entrenadores y preparadores físicos con objeto de mejorar la periodización y programación de la carga de los jugadores en las diferentes sesiones de entrenamiento del microciclo, y así conseguir una mejor preparación de los jugadores considerando el 'escenario'[12] del siguiente partido.

II. Se han identificado dos categorías diferentes para las actividades de TM en entrenamiento: parámetros de volumen, que incluyen la distancia total, la distancia de alta velocidad de carrera, la distancia equivalente y el trabajo metabólico; y parámetros de intensidad, incluyendo la distancia de muy alta velocidad de carrera y la distancia a sprint. Esto resulta de gran utilidad para la programación y diseño de tareas específicas contextualizadas al juego, ya que los preparadores físicos podrán focalizarse más a un tipo de variables u otras en función del objetivo físico de la tarea (estudio 1).

III. Entender cómo afecta el despido del entrenador al rendimiento físico de los jugadores es útil para que los preparadores físicos puedan optimizar la planificación de la carga (volumen e intensidad de las tareas) y evitar grandes cambios que puedan afectar negativamente a la forma física de los jugadores. En este sentido, con objeto de realizar un rendimiento físico similar al que se realizaba con el entrenador destituido, se debería incrementar la carga física de los jugadores en entrenamiento tras la llegada del nuevo entrenador (estudio 2).

[12] El 'escenario' es referido al contexto del próximo partido, considerando la localización del encuentro, el periodo de la temporada y la calidad del rival al que tenga que enfrentarse.

IV. Ya que los jugadores necesitan un periodo de tiempo para asimilar los cambios que pueda realizar en el estilo de juego del nuevo entrenador y que se vea reflejado en el rendimiento físico, podría resultar conveniente realizar un trabajo físico específico adicional en las primeras semanas tras la llegada del nuevo entrenador (estudio 2).

V. Conocer el efecto que el cambio de entrenador puede tener en el comportamiento físico de los jugadores resulta de buena utilidad para los clubes con objeto de determinar si el cambio de entrenador podría suponer un estímulo positivo para los jugadores, o por el contrario resultar en un fenómeno estresante (estudio 2).

VI. Con objeto de conseguir un mejor rendimiento físico en el partido, las sesiones de entrenamiento y/o tareas en el fútbol profesional deben caracterizarse por mantener un volumen reducido y una intensidad o velocidad. Esto significa que los futbolistas deberían realizar una HIRD alta en el microciclo, pero sin mostrar una TD elevada (estudio 3).

VII. La recopilación individualizada de los datos de los jugadores a lo largo de la temporada permite predecir el 'patrón' de carga en el partido. Esta información resulta de gran utilidad para entrenadores y preparadores físicos ya que ayuda a conocer el nivel de 'preparación' de los jugadores para hacer frente a las exigencias del partido, y cómo la TL afecta a la ML en un contexto determinado (estudio 3).

VIII. Todos los expertos que participaron en el estudio 4 analizando el efecto del periodo de cuarentena por coronavirus coinciden que se debería permitir un mínimo de 3-4 semanas de preparación tras la vuelta a los entrenamientos antes de retomar la competición para poder realizar un incremento progresivo de la carga. Además, será necesario dosificar los minutos de juego de los jugadores realizando continuas sustituciones y rotaciones de jugadores. En este sentido, permitir excepcionalmente a los equipos realizar un mayor número de sustituciones durante el partido ayudaría a la realización de este propósito.

XIV. Futuras Líneas de Investigación

Futuras Líneas de Investigación

Una vez se han cumplido con los objetivos pretendidos en la presente Tesis Doctoral y se ha dado respuesta a las distintas hipótesis de investigación planteadas a través de los resultados obtenidos en los diferentes estudios, se han encontrado ciertas limitaciones que deberían ser consideradas en futuras líneas de investigación con objeto de profundizar en el conocimiento y comprensión sobre el control y monitorización de la carga de los futbolistas:

1. Si bien los diferentes estudios han mostrado resultados estadísticamente significativos en las diferentes pruebas realizadas con las muestras de los tres equipos de Primera, Segunda y Segunda División B, una limitación de esta Tesis Doctoral ha sido contar con sólo un equipo de cada categoría. En este sentido, disponer de datos de un mayor número de equipos en cada una de las tres categorías posibilitaría aumentar los niveles de generalización.
2. A partir de los modelos de predicción de la carga de entrenamiento realizados en el estudio 1, futuros estudios deberían intentar identificar cómo los factores contextuales podrían alterar la carga de entrenamiento y la relación de esa carga con los diferentes contenidos realizados en entrenamiento. En este sentido, resultaría de especial interés considerar la interacción de las diferentes respuestas físicas de los jugadores con los elementos técnico-tácticos que realizan los jugadores en dichas acciones con objeto de conseguir un mayor entendimiento del juego.
3. Al investigar el efecto que produce la destitución de un entrenador a mediados de temporada en el estudio 2, analizar los cambios en las respuestas físicas durante las 4 semanas previas y posteriores al cambio de entrenador puede no ser tiempo suficiente para reflejar un posible cambio en el comportamiento físico ya que los jugadores podrían necesitar un periodo de adaptación y aprendizaje del estilo de juego propuesto por el entrenador nuevo. Además, sólo se disponía de datos de tres equipos compitiendo en diferentes categorías. Por tanto, futuros estudios deberían analizar un número mayor de equipos y durante un periodo de tiempo más prolongado.

4. De los modelos de predicción de la ML a partir de la TL realizada por los futbolistas durante la semana de entrenamiento previa que han sido desarrollados en el estudio 3, ya que existe bibliografía que muestra grandes diferencias en las respuestas físicas mostradas por los futbolistas en las diferentes ligas y considerando diversos factores, sería recomendado analizar un mayor número de equipos, de diferentes países y en diferentes contextos con objeto de establecer modelos más precisos.
5. Ya que la aparición de la pandemia mundial del coronavirus en el año 2020 es una situación insólita y sin precedentes, no existía bibliografía sobre los efectos de parar drásticamente la actividad en mitad del periodo competitivo en el rendimiento físico de los futbolistas de élite. Por tanto, sería de gran interés obtener información del comportamiento de la carga física de los jugadores en su vuelta a la actividad, con objeto de analizar el efecto sobre el rendimiento de los jugadores, así como la repercusión en la incidencia de lesiones a corto y largo plazo.