Universidad del País Vasco
Euskal Herriko Unibertsitatea
NAZIOARTEKO BIKAINTASUN CAMPUSA
CAMPUS DE EXCELENCIA INTERNACIONAL

**DOCTORAL PROGRAMME IN PHYSICAL ACTIVITY AND SPORT**

**Faculty of Education and Sport**

**Physical Education and Sport Department**

# Differentiated perceived training and match loads assessment in a professional soccer team

**DOCTORAL THESIS**

By

**Unai Xabier Azcárate Jiménez**

Vitoria-Gasteiz, 2020

eman ta zabal zazu

Universidad del País Vasco — Euskal Herriko Unibertsitatea

NAZIOARTEKO BIKAINTASUN CAMPUSA
CAMPUS DE EXCELENCIA INTERNACIONAL

**DOCTORAL PROGRAMME IN PHYSICAL ACTIVITY AND SPORT**

**Faculty of Education and Sport**

**Physical Education and Sport Department**

# Differentiated perceived training and match loads assessment in a professional soccer team

**DOCTORAL THESIS**

By

**D. Unai Xabier Azcárate Jiménez**

Thesis directed by

**Dr. Asier Los Arcos Larumbe**

University of the Basque Country, UPV/EHU

**Dr. Javier Yanci Irigoyen**

University of the Basque Country, UPV/EHU

Vitoria-Gasteiz, 2020

*Dedicado a mi padre, Serafín, y a mi madre, Anabel,*

*por brindarme la oportunidad de decidir y apoyarme en todas mis decisiones*

*A mi hermana Leire y mi cuñado Rubén,*

*por su constante e incansable preocupación por mí y mi trabajo*

*A mi compañera de viaje, Marina*

*por creer en mí en todo momento*

*A mis dos sobrinos, Irati y Martín,*

*simplemente por dejarme ser su tío y sentirme afortunado por ello*

*A mi primo Igor y su mujer Sheila,*

*por ser algo más que mis primos*

*A toda mi familia biológica y política,*

*por ayudarme a ser quien soy ahora*

*A mi grupo de amigos,*

*por estar siempre a mi lado y brindarme su compañía*

# Prólogo y agradecimientos

Desde mi infancia, he de reconocer que siempre he sido una persona muy inquieta en el ámbito personal. Tan pronto un día disfrutaba desarrollando una tarea concreta, como que, justo al día siguiente, me interesaba por otra totalmente diferente. Sin embargo, siempre ha habido una constante en el núcleo de mis intereses, una actividad que nunca he dejado de practicar: el fútbol.

Quizás lo que más me ha atraído de este deporte y su práctica es que, para mí, siempre ha constituido un reto, en el cual día tras día debía dar lo mejor de mí para aprender y enseñar al mismo tiempo. En cuanto a mi particular historia con este deporte, tuve un inicio tardío comparándolo con el resto de mis amigos, esto me llevo a tener que desarrollar un conjunto de habilidades en un periodo de tiempo más reducido que el resto de mis compañeros. Sin embargo, debo confesar que en aquellos años, cuando llegaba la hora de ir a entrenar, yo lo sentía como uno de los mejores momentos de la semana y siempre deseaba fervientemente que llegara la hora de enfundarme las botas y salir al campo de fútbol, donde me olvidaba de todo y simplemente disfrutaba del momento y de mis amigos. El fútbol era lo que me hacía sentir vivo.

Desde entonces hasta hoy, mi vida ha estado siempre ligada al fútbol. Con mis primeras experiencias en la escuela de fútbol de mi pueblo hasta la actualidad, no he dejado de practicar y vivir el fútbol. Guardo recuerdos imborrables de todo lo que el fútbol me ha dado pero, también, de todo aquello que he tenido que sacrificar. Tanto las victorias y logros como las derrotas y fracasos, me acompañan durante los años y, con gran frecuencia en las reuniones con amigos, se rescatan para ser relatadas como recuerdo de grandes momentos para todos, y enseñanzas de vida.

No puedo mencionar de forma individual a cada entrenador y compañero de los cuales guardo un recuerdo y cariño especial puesto que la lista sería interminable. Ellos son los que me dieron la oportunidad de disfrutar y formarme y siempre les estaré agradecido. Por ello, me gustaría reconocer ahora, de modo general, a todas las personas que formaron y forman parte de los clubs en los que he podido jugar y los cuales me permitieron descubrir el amor por este deporte. Entre ellos, agradezco el tiempo pasado en el C.D. Aluvión, C.D. Ribaforada, C.D. Tudela 1999, C.D. Alfaro y por último C.D. Corellano. A lo largo de más de

15 años he vestido con orgullo y satisfacción la camiseta de todos estos clubs tanto como jugador como de preparador físico. Guardo una y mil experiencias vividas en ellos que me han hecho creer en este deporte, me han ilusionado, satisfecho, formado y me han permitido adquirir un aprendizaje continuo e ininterrumpido.

Por otra parte, no puedo dejar de mencionar ahora el apoyo total e incasable de mi familia a lo largo de todo este tiempo. Gracias a mi padre por demostrarme la importancia del compromiso con el trabajo y mostrarse siempre deseoso de aprender. Gracias a su tenacidad y seriedad, he aprendido que, haga lo que haga, debo siempre dar mi mejor versión. Gracias a mi madre, por curarme las heridas tras un partido, aguantar el malhumor de la derrota y recibirme siempre con una sonrisa. No existen palabras que puedan resumir el agradecimiento y orgullo tan grande que siento por tenerles en mi vida. Gracias a mi hermana, Leire, por llevarme de la mano a lo largo de la vida y mostrarme que juntos, todo es más fácil y divertido. Le agradezco también a ella el haber multiplicado la felicidad por tres con la llegada de mis dos sobrinos, Irati y Martín, y mi cuñado, Rubén. Ahora la familia está completa. No puedo olvidarme tampoco de mi primo Igor, hijo único pero que es como un hermano para mí, y con quien he tenido la oportunidad y gran suerte de compartir tardes de fútbol en el C.D. Ribaforada. Le doy las gracias también a su mujer, Sheila, o como a mí me gusta llamarle "apegada", por quarernos y aguantarnos a los dos.

Agradezco a mis suegros, Mª Carmen y Santi el estar pendientes de mí en todo momento, cuidarme como un hijo más y animarme a continuar y progresar en los malos momentos y a mi cuñado Javi, por interesarse y escucharme en cada momento que tenemos juntos.

Por otra parte, esta tesis doctoral se ha llevado a cabo gracias al apoyo de numerosas personas que me han aportado el conocimiento que necesitaba para lograr este reto. En este sentido, quisiera agradecer de forma muy especial a todos los profesores de la Facultad de Educación y Deporte de la Universidad del País Vasco (UPV/EHU) que tras diez años en esta "casa" me han hecho crecer como persona y como profesional. En este punto, debo mencionar especialmente a Asier Los Arcos, mi director de tesis. Siempre le agradeceré su búsqueda de la perfección, su valioso tiempo y el haberme dado la oportunidad de conocer y vivir esta experiencia. Gracias por ser el modelo en el que fijarme y del cuál aprender, inculcándome unos valores formativos que me servirán de apoyo para toda la vida.

Gracias también a Javier Yanci Irigoyen por su organización, todo su conocimiento, experiencia, sabiduría e inteligencia. Gracias por su buen humor, sonrisa y sobre todo paciencia en el desarrollo de este proyecto. Todo ello han sido piezas fundamentales en mi formación pre-doctoral.

A Julen por su predisposición a prestarme toda la información y sabiduría cuando me fue necesaria. Por último, y no menos importante, agradezco a Iván Agustín, "pupilo de la casa", todo su trabajo, colaboración, esfuerzo, pasión y ganas por mejorar.

Al mismo tiempo, dar las gracias también a todos mis compañeros de la universidad por las experiencias vividas durante estos años maravillosos de carrera y máster. Agradezco enormemente y desde el corazón a Ukerdi, Latatu, Cubillas, Lander e Iván Acereda por todos los momentos que hemos compartido juntos.

No puedo olvidarme de todos aquellos que han convivido conmigo estos años en Vitoria-Gasteiz: David, Eduardo, Picabea, Iñigo, Javo e Iván Santafé por toda vuestra compañía, amistad y gratitud. A Gorka, Iñaki, Diego y todos los demás compañeros del San Ignacio por su colaboración, por dejarme compartir vestuario y acogerme con los brazos abiertos.

Al Club Deportivo Mirandés, cuerpo técnico y jugadores por darme la oportunidad de desarrollar este proyecto, mostrándose dispuestos a ayudarnos y colaborar en el transcurso del proyecto para que esta tesis haya sido posible. Habéis prestado vuestra predisposición en todo lo que ha sido posible para llevar a cabo todos los pasos de este minucioso proyecto de investigación. Gracias a la directiva y entrenadores por permitirme disfrutar de vuestro momento.

Agradezco a Alfonso Sanz, profesor que marcó profundamente mi etapa de secundaria con su capacidad para orientarme en la vida cuando me hizo falta y el cariño con el que nos enseñaba

Me gustaría darle las gracias a mi amigo David, por siempre estar pendiente del desarrollo y formación de esta tesis, por compartir conocimientos, valorar y apreciar mi trabajo y animarme a seguir adelante en este bonito proyecto. Agradezco a toda mi "cuadrilla", Luis Ángel, Luis, Javier, David L. Joseba, Jorge y Andoni por acompañarme a lo largo de toda la vida y ponerle alegría a la misma.

Agradezco a mi "segunda cuadrilla", Miguel, Álvaro, Isidro, Javier, Ruiz, y Merce por su magnífico entendimiento de lo que suponía para mí el esfuerzo de desarrollar este proyecto.

Por último, quisiera hacer una mención especial a Marina, mi compañera de vida, por hacerme entender que uno nunca debe rendirse. Gracias por comprenderme y apoyarme en cada decisión que tomo, animarme a seguir creciendo, por su cariño, respeto, su fuerza y por enseñarme que es necesario saber controlar los estados de ánimo para poder progresar en la vida. Gracias por hacerme ser quién soy ahora.

No importa cuantas veces te equivocas, o con qué lentitud progresas, sigues estando muy por delante de los que no lo intentan.

(Anthony Robbins)

# Declaración:

Yo, Unai Xabier Azcárate Jiménez me identifico como el autor de esta tesis doctoral, que, junto con la ayuda y apoyo de mis dos directores, el Dr. Asier Los Arcos Larumbe y el Dr. Javier Yanci Irigoyen, hemos compartido desde el minucioso trabajo de recogida, elaboración y diseño de la investigación hasta la redacción del documento final. He abordado cada paso del proyecto de trabajo de forma exhaustiva, organizada y sistemática. Para todo ello, y como parte del presente proyecto de investigación, he asistido a las sesiones necesarias de test para la evaluación de las diferentes capacidades físicas de los jugadores, a diferentes sesiones de entrenamiento del equipo, a sesiones específicas para el trabajo individualizado en la readaptación de lesiones y a varios partidos de fútbol oficiales de la Segunda División Española durante la temporada 2015-2016. Al mismo tiempo, he visualizado y analizado los partidos de fútbol oficiales a los que no he podido asistir de forma presencial. Además, verifico y respaldo que los datos brutos requeridos para la elaboración de este proyecto han sido recogidos con seriedad, rigurosidad y profesionalidad con la colaboración del preparador físico del equipo.

Durante la ejecución de la toma y análisis de datos me ha sido demandada una alta capacidad de concentración, atención y sobre todo, de habilidad para responder de forma rápida y resolutiva a situaciones imprevistas generadas durante las diferentes fases del trabajo. Así mismo, en esta fase del proyecto he sido el responsable de organizar y cumplimentar la documentación necesaria para el desarrollo de la sesión de los test de condición física, de solicitar el material necesario a la Facultad de Educación y Deporte de la Universidad del País Vasco / Euskal Herriko Unibertsitatea (UPV/EHU) y/o a terceras entidades, de gestionar la compra de material desechable, así como de la realización de los informes individualizados para los jugadores de fútbol profesional que posteriormente fueron presentados en las instancias del Club. Después de cada toma de datos he realizado el análisis e interpretación de los mismos. Estas tareas las he realizado a la vez que llevaba a cabo una exhaustiva y formativa lectura de los trabajos científicos publicados en relación con el futbol.

En una fase posterior he contrastado los resultados obtenidos en mi proyecto científico con los publicados en la literatura científica relacionados con la temática. De esta forma, he progresado en la elaboración y redacción del conjunto de estudios que se reparten y forman el capítulo 3. Bien es cierto que nada de esto hubiera sido posible sin la guía de mis directores, Asier y Javier. Ellos han formado el pilar base sobre el que se ha levantado este proyecto. Han conseguido formarme profesional y personalmente hasta lo que ahora soy, involucrándose desde el inicio en la selección del tema, pasando por todos los procesos de creación y redacción de los estudios, hasta su publicación en diferentes revistas de ámbito científico. Además, durante este proceso de formación he colaborado con investigadores especialistas en el área a nivel nacional e internacional que me han aportado un gran bagaje de experiencia y conocimiento que me ha servido para mejorar la calidad del trabajo. De forma complementaria, he diseñado otros proyectos de investigación paralelos al ámbito de investigación que seguía en esta tesis doctoral, cuyos resultados los he presentado como artículos científicos, comunicaciones orales y posters en congresos nacionales e internacionales. Ninguno de estos resultados forman parte de la presente tesis doctoral pero se pueden consultar en el apartado *anexos*. Además, he ejercido como revisor de artículos científicos para diferentes revistas nacionales e internacionales.

Para el desarrollo de las investigaciones no he contado con financiación de ningún tipo. No obstante cabe mencionar que la UPV/EHU y el centro de alto rendimiento Zentrum Sport de Barañain (Navarra) han proporcionado parte del material necesario para la fase de recogida de datos. Además, esta tesis doctoral no presenta conflicto de intereses por parte de los autores ni familiares.

# Consejos para la lectura:

La tesis doctoral está elaborada y presentada en formato de compendio de publicaciones. Esta tesis doctoral está escrita totalmente en inglés salvo las partes genéricas correspondientes a los primeros apartados mencionados hasta este punto. Con ello se pretende que el trabajo consiga una mayor difusión a nivel internacional. En el primer capítulo, a modo de aproximación al problema, y con el objetivo de contextualizar la investigación realizada, se presenta el marco teórico. Este capítulo inicial se fundamentará en los estudios científicos que han investigado sobre las demandas físico-fisiológicas del partido y el entrenamiento en el fútbol profesional. Concretamente, en los trabajos que han valorado las cargas interna y externa del entrenamiento y el partido, su variabilidad y sus efectos en la condición física de los jugadores. Además, fueron revisados los estudios que han cuantificado la carga de entrenamiento y partido en semanas de entrenamiento del periodo competitivo en las cuales se disputaron uno o varios partidos. En el segundo capítulo, se exponen los objetivos de la tesis doctoral. Posteriormente, en el tercer capítulo se presentan tres estudios científicos publicados o aceptados para su publicación en revistas internacionales indexadas en la lista JCR o Scopus y un estudio en revisión en una revista JCR. Todos los estudios han sido redactados en el idioma requerido por las revistas en el que han sido publicados (lengua inglesa). Con el objetivo de facilitar la lectura de la tesis doctoral, el formato del conjunto del texto y las referencias bibliográficas de los cuatro artículos han sido unificados. Los estudios presentados en esta tesis doctoral siguen una misma temática y línea de investigación basada en la descripción, el análisis y la valoración de las cargas de entrenamiento y partido acumuladas por los jugadores de fútbol profesional durante la temporada.

En el tercer capítulo se muestran cuatro subapartados que corresponden a los estudios desarrollados para esta tesis doctoral. El primer estudio, titulado "*Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load*", analiza la carga semanal acumulada atendiendo a la participación de los jugadores en el partido y a la longitud de los microciclos semanales. El segundo estudio, titulado *"Are acceleration and cardiovascular capacities related to perceived load in professional soccer players?",* analiza la condición física inicial de los futbolistas y su relación con la carga percibida de entrenamiento y partido al comienzo de la temporada. El tercer estudio, titulado "*Differentiated perceived match load and its variability according to playing position in professional soccer players during an entire season",* valora la carga percibida por el jugador y su variabilidad en función de la posición que ocupa en el terreno de juego durante el partido. Por último el cuarto estudio, titulado "*Variability of professional soccer players' perceived match load after sucesive matches",* estudia la carga percibida de partido atendiendo a la participación del jugador en varios partidos dentro de la misma semana y al tiempo de participación en cada uno de ellos.

En el cuarto capítulo se presentan las conclusiones generales de la tesis doctoral. Además, en los capítulos quinto, sexto y séptimo se exponen las aplicaciones prácticas, las limitaciones y las futuras líneas de investigación.

Por último, en el octavo capítulo, denominado "*Attachments*", se presentan las referencias de los artículos publicados en las revistas de investigación y que forman parte de la tesis y su correspondiente índice de calidad. Además, se presentan de manera resumida varias publicaciones científicas adyacentes a la tesis, comunicaciones orales y posters presentados en congresos y jornadas nacionales e internacionales relacionados con la tesis doctoral en las que el doctorando ha participado. Por último, se informa sobre aspectos relevantes en la formación predoctoral realizada por el doctorando.

# List of abbreviations:

***A*** = away match

***AFL*** = Australian Football League

***AMP*** = average metabolic power

***ASR*** = anaerobic speed reserve

***AU*** = arbitrary units

***AvM*** = advanced midfielder

***bpm*** = beats per minute

***CB*** = central back

***CD*** = central defender

***CK*** = creatine kinase

***CL*** = confidence limit

***CupM*** = Cup match

***CM*** = central midfielder

***CODA*** = change of direction ability

***CT*** = collective technique

***Cup*** = king's Cup matches

***CV*** = coefficient of variation

***DOMS*** = delayed onset muscle soreness

***dPE*** = differentiated perceived exertion

***DRF*** = index of force application technique

***dRPE*** = differential ratings of perceived exertion

***dRPE TL*** = differential ratings of perceived exertion in training load

***dRPE ML*** = differential ratings of perceived exertion in match load

***EL*** = external load

***ES*** = effect size

***FIFA*** = Fédération Internationale de Football Association

$F_0$ = theoretical maximal force

***FB*** = full back

***FM*** = Friendly match

***F-V profile*** = force-velocity mechanical profile

***GK*** = goalkeeper

***GPS*** = global positioning system

*Abbreviations*

***H*** = home match

***HR*** = heart rate

***HR<sub>max</sub>*** = maximal heart rate

***HSR*** = high-speed running distance

***IL*** = internal load

***iTRIMP*** = individualized training impulse

***JCR*** = journal citation reports

***LFP*** = professional league football

***M1 and M3*** = microcycle 1 and 3 (two-game weeks)

***M2*** = microcycle 2 (three-game weeks)

***M4 and M5*** = microcycle 4 and 5 (one-game weeks)

***MAS*** = maximal aerobic speed

***MD*** = match day

***MD-1*** = day before match

***ML*** = match load

***N-S*** = Non-Starters

***OM*** = Official match

***OMS*** = optical measurement systems

***PLY*** = plyometric

$P_{max}$ = maximal horizontal external power

***Post_cup*** = match played after (same week) the King's Cup matches

***PPs*** = playing position

***Pre_Cup*** = match played before (same week) the King's Cup matches

***RF*** = ratio of forces

***RPE/PE*** = perceived exertion

***RPE-B*** = rating of perceived breathlessness exertion

***RPE-L*** = rating of perceived leg exertion

***RSA*** = repeated sprint ability

***R. Speed*** = reaction speed

***ST*** = starters

***S*** = striker

***SD*** = standard deviation

***sRPEmus*** = local-muscular perceived exertion

***sRPEmus-TL*** = session rating of local-muscular perceived exertion in TL

***sRPEmus-ML*** = session rating of local-muscular perceived exertion in ML

***sRPEres*** **=** central-respiratory perceived exertion

***sRPEres-TL*** = session rating of central-respiratory perceived exertion in TL

***sRPEres-ML*** = session rating of central-respiratory perceived exertion in ML

***SSGs*** **=** small-sided soccer games

***TD*** = total distance

***TeS*** **=** test session

***THSR*** **=** total high-speed running distance

***TL*** = training load

***TS*** **=** training session

***TSD*** **=** total speed distance

***UM-TT*** **=** Montreal University Track Test

***UPV/EHU*** = University of the Basque Country

***VFL*** = Victorian Football League

$VO_{2max}$ = maximal oxygen consumption

$V_0$ = theoretical maximal velocity

***WB*** **=** wide back

***WM*** **=** wide midfielder

***WnB*** **=** wing back

**Resumen de la tesis doctoral en uno de los idiomas oficiales de la Comunidad Autónoma del País Vasco**

La tesis doctoral tiene como objetivo la valoración de la carga diferencial percibida de entrenamientos y partidos en un equipo de fútbol profesional que competía en la segunda división española, conocida por motivos publicitarios como *Liga Adelante*. En el primer capítulo de la tesis doctoral se presenta, a modo de marco teórico o introducción, el conocimiento científico existente hasta el momento sobre las demandas físico-fisiológicas del entrenamiento y el partido en el fútbol. En concreto, el marco teórico de la tesis doctoral resume la evidencia científica existente sobre la evaluación de la carga interna y externa de entrenamiento y partido, su variabilidad a lo largo de un periodo de temporada y/o pretemporada y su relación con la condición física de los jugadores. Además, se expone una introducción sobre los estudios publicados en la literatura científica que cuantifican la carga de entrenamiento y partido en semanas del periodo competitivo en las que se disputaron uno o varios partidos. Puesto que varias investigaciones han observado que el partido es la sesión de mayor carga físico-fisiológica de la semana y que la periodización de la semana de entrenamiento no es sencilla para el preparador físico, la tesis doctoral pretende aportar conocimiento en este campo con el fin de dar respuesta a la problemática que los preparadores físicos encuentran en su día a día en relación a la periodización de la carga de entrenamiento con respecto al partido. En relación a las sesiones de entrenamiento, este conocimiento permitirá optimizar la preparación del futbolista en la competición mediante la eficiente distribución de las cargas de entrenamiento. De este modo, se podrá optimizar la recuperación post-partido y evitar la fatiga previa al siguiente partido, reducir el riesgo de lesiones en los jugadores y conocer el estado físico inicial de los jugadores mostrando de esta forma la asimilación a la carga interna que soportan. Por otro lado, en relación a la carga de partido, la cuantificación de la carga permitirá a los preparadores físicos conocer la carga física-fisiológica que soporta cada jugador en el campo en función de la posición que ocupa en el mismo. Esta información podrá ser considerada para adaptar las sesiones de recuperación y las sesiones previas al partido de la semana de entrenamiento con el fin de preparar el siguiente partido

En el segundo capítulo se exponen los objetivos que se persiguen con la elaboración de esta tesis doctoral, que son: a) comparar la carga de entrenamiento semanal (carga percibida diferenciada: respiratoria y muscular) en función de su longitud y de la participación de los jugadores en los partidos oficiales durante el periodo competitivo de la temporada; b) analizar las asociaciones entre la condición física de los jugadores de fútbol profesional y la dRPE TL o dRPE ML acumulada durante varios periodos de la temporada; c) evaluar la dRPE ML y su variabilidad en función de la posición que ocupan los jugadores en el campo durante una temporada completa; y d) evaluar la dRPE ML y CupM en jugadores de fútbol profesional que participaron en sucesivos partidos durante una misma semana o varios microciclos semanales donde habían sucedido varios partidos por semana.

En el tercer capítulo se exponen cuatro artículos científicos (tres de ellos publicados o aceptados para su publicación y uno en revisión) en revistas indexadas en la lista JCR o Scopus. Este capítulo está compuesto por cuatro subapartados pertenecientes cada uno de ellos a los estudios que forman el conjunto de trabajos de la tesis doctoral presentada por compendio de publicaciones. El primer estudio, titulado "*Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load"*, valora la carga semanal acumulada atendiendo a la participación de los jugadores en el partido y a la longitud de los microciclos semanales. El segundo estudio, titulado *"Are acceleration and cardiovascular capacities related to perceived load in professional soccer players?",* analiza la condición física inicial de los futbolistas y su relación con la carga percibida de entrenamiento y partido al comienzo de la temporada. En el tercer estudio, titulado "*Differentiated perceived match load and its variability according to playing position in professional soccer players during an entire season",* valora la carga percibida por el jugador y su variabilidad en función de la posición que ocupa en el terreno de juego durante el partido. Por último, el cuarto estudio desarrollado en esta tesis doctoral, titulado "*Variability of professional soccer players' perceived match load after sucesive matches",* analiza la carga percibida de partido atendiendo a la participación del jugador en varios partidos dentro de la misma semana y al tiempo de participación en cada uno de ellos.

En el cuarto capítulo se exponen las conclusiones generales de la tesis doctoral. Atendiendo a los resultados obtenidos, la participación de los jugadores de fútbol profesional en el partido previo condiciona la carga de entrenamiento acumulada a lo largo de la semana. En concreto, a mayor participación en el partido, mayor carga de entrenamiento semanal independientemente de las estrategias de entrenamiento llevadas a cabo por el entrenador para compensar la falta de minutos de competición de algunos jugadores. Además, se ha observado que la longitud de las semanas de entrenamiento no parece afectar a la carga de entrenamiento semanal acumulada por los jugadores. Por otro lado, parece ser que tanto la carga de entrenamiento como la de partido supone una mayor implicación neuromuscular que respiratoria. Siguiendo en esta línea, se concluye que el esfuerzo en un partido de fútbol es diferente dependiendo de la posición que el jugador ocupa en el campo, pero no siempre en ambas dimensiones del esfuerzo percibido (respiratorio o muscular). Estos resultados sugieren que el esfuerzo percibido diferencial mejora la evaluación de la carga general de partido percibida en fútbol y puede ayudar a diseñar y planificar las sesiones de entrenamiento previas y posteriores al partido para llegar en las mejores condiciones físicas y fisiológicas posibles al siguiente encuentro. Para concluir con este apartado sobre la importancia de la evaluación del esfuerzo percibido diferencial en el fútbol, se proponen futuros trabajos de investigación en los que se valoren las consecuencias de otros factores contextuales de la competición (p.ej. jugar en casa o jugar fuera) en la carga percibida de partido. Por último, se concluye que la carga interna de partido evaluada a través de la dRPE-ML apenas varía a lo largo de un largo periodo de tiempo (21 partidos de liga y copa disputados a lo largo de 8 semanas de temporada).

En el capítulo quinto se presentan las diferentes aplicaciones prácticas del proyecto. Las estrategias de entrenamiento diseñadas en la primera sesión de la semana, enfocadas a la compensación de la carga del partido, no suponen una carga física suficiente para los jugadores que no compitieron. Por esta razón, se sugiere la realización de estrategias de entrenamiento compensatorias a lo largo de la semana para los jugadores que no participaron completamente en el partido, siempre y cuando se asegure la recuperación post-partido y se evite la fatiga previa al siguiente partido. Además, teniendo en cuenta la monitorización de la carga de entrenamiento y partido, la tesis doctoral muestra la importancia de la utilización del esfuerzo percibido diferencial para cuantificar y prescribir la carga de entrenamiento durante la semana de entrenamiento. En cuanto a la variabilidad de la carga de partido en función del puesto específico de los jugadores, se sugiere la necesidad práctica de diseñar planes de entrenamiento semanales de manera individualizada para los jugadores en función de la posición que ocupan en el campo con el fin de incrementar el rendimiento de cada jugador. Por último, siguiendo con la línea de la aplicación práctica en relación a la variabilidad, la pequeña variabilidad encontrada en la carga de partido diferencial entre la consecución de partidos de liga y copa a lo largo de una temporada sugiere que una recuperación post-partido de 72 horas permite una recuperación física y fisiológica suficiente, permitiendo al jugador encontrarse en disposición para competir en el siguiente partido.

En el sexto capítulo se exponen las limitaciones de la tesis doctoral. Debido a razones externas, el estudio no pudo cuantificar la carga externa de entrenamiento y partido y llevar a cabo la medición de los test de condición física al final del periodo competitivo. Por otro lado, las diferentes propuestas estadísticas de los revisores de la revistas en las que han sido publicados los artículos de la tesis, han supuesto la utilización de distintas técnicas estadísticas, provocando que no haya una uniformidad en los análisis utilizados. Sin embargo, ha supuesto un enriquecimiento en el análisis estadístico de los datos que podrá ser empleado en futuros estudios. Por último, una mayor muestra habría aportado mayor peso a la investigación, pero debido al nivel competitivo del equipo, es difícil poder contar con un mayor número de futbolistas profesionales.

Las futuras líneas de investigación se presentan en el séptimo capítulo. En el mismo, se expone que sería interesante replicar los estudios de la tesis doctoral utilizando la carga externa e interna simultáneamente para comparar los resultados. Además, la investigación en relación a la carga percibida diferencial podría ser llevada a cabo también en un nivel competitivo inferior, donde los equipos cuentan con menos recursos económicos para evaluar la cuantificación de la carga de entrenamiento y partido. Siguiendo en la línea de la cuantificación de la carga en jugadores de fútbol amateur, además de la carga de entrenamiento, sería interesante tener en cuenta la carga de trabajo (p.ej. carga laboral) y analizar su influencia en el rendimiento físico del jugador de futbol.

Para finalizar, en el capítulo octavo se presentan los anexos que complementan el estudio. En este apartado aparecen los artículos publicados en las revistas de investigación y que forman parte de la tesis en el formato solicitado por las correspondientes editoriales. En un segundo subapartado de este capítulo se ha añadido información sobre las revistas donde se han publicado los artículos, además del grado de cumplimiento de la tesis doctoral atendiendo a los requisitos establecidos por la comisión académica de doctorado para la presentación de tesis redactadas en formato de compendio de publicaciones. En el siguiente subapartado, se presentan varias publicaciones científicas, comunicaciones orales y posters presentados en congresos y jornadas científicas de ámbito nacional e internacional relacionados con el tema desarrollado en la tesis doctoral en las que ha participado el doctorando y adyacentes a la tesis. Por último, se desarrollan apartados referentes a la formación predoctoral realizada a lo largo de los años de formación académica.

# INDEX OF CONTENTS

# Chapter 1

## The approach to the problem

# CHAPTER 1. THE APPROACH TO THE PROBLEM

### *Subchapter 1.1. A response to a practice demand in a soccer team*

The aim of applied sciences is to produce new knowledge which is intended to be useful for the specific purpose of increasing the effectiveness of some human activity (Niiniluoto, 1993). Therefore, a doctoral thesis of this kind shall address and respond to the needs of professional sport coaches from a scientific perspective. In soccer, specifically, scientific research must aim at acquiring knowledge that enables the optimization of training processes, the improvement of the team performance and the avoidance of injuries that would keep players off the court for some time. In this connection, the current doctoral thesis aims at meeting the needs and concerns of the training staff working with a Spanish soccer team that competes in the Second Division.

The physical trainer's main concern was the need to measure the physical and physiological response of players during the training sessions as well as during matches, both friendly and official matches. Despite the fact that the team competes in the Second Division of Spanish Professional Soccer League, the team did not have HR and GPS devices available at the time, in order to carry out a quantification of the IL (Clemente et al., 2017; Jaspers, Brink, Probst, Frencken, & Helsen, 2017) and EL (Malone et al., 2018; Stevens, De Ruiter, Twisk, Geert, & Beek, 2017). Furthermore, it should be noted that not all football fields in the Second Division have OMS technology that can provide data on external quantification. In this case, the team chosen for this research did not have the afore-mentioned technology, which meant that data on external quantification data was available for just some matches played away in other fields. On the other hand, the research team did have temporal access to measurement systems of HR and GPS, which could have been used in the data collecting process for the doctoral thesis. Yet, its use would not have been useful from a practical point of view since the team did not have had access to these systems all along the season. Thus, it was finally decided that the research method used would be one that could also be used by the team, later on. For this reason, one of the first questions to be posed by the coaching staff was in relation to the method that could be used to measure players' load during training sessions and throughout the different competition periods. As it will be argued and developed in this work, the researcher suggested using PE (Foster et al., 2001), and more specifically, dRPE for this purpose (Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014; Barrett, McLaren, Spears, Ward, & Weston, 2018; Los Arcos, Mendez-Villanueva, Yanci, & Martinez-Santos, 2016; McLaren, Smith, Spears, & Weston, 2017). Within this PE issue, it was considered of particular importance for this research to thoroughly explain the difference of the PE and the dRPE constructs. In fact this is a relevant part of this Doctoral Thesis, which has been conducted through PE assessed in order to quantify the internal TL in the case of the professional soccer players who participated in this study.

As official matches are considered the most important session of the week, physical trainers have as a main objective to prepare players' fitness state so that they can compete at their best every weekend. Bearing this in mind, the weekly accumulated TL and its distribution should ensure sufficient after-game recovery time and it should avoid any fatigue prior to the next game (Djaoui, Diaz-Cidoncha, Hautier, & Dellal, 2016; Ispirlidis et al., 2008; Rampinini et al., 2011; Silva et al., 2018; Thorpe et al., 2015). For this reason, the physical trainer previously mentioned considered that it would be necessary to measure weekly TL (i.e. including that from the game) accumulated by players depending on the type of week (i.e. Saturday-Saturday, Sunday-Sunday, Saturday-Sunday and Sunday-Saturday). Moreover, due to the fact that not all players can take part in a game, the most challenging session of all (Castagna, Varley, Póvoas Araújo, & D'Ottavio, 2017; Fessi et al., 2016; Ispirlidis et al., 2008; Rampinini et al., 2011), and also the fact that there are considerable differences in accumulated TL among those who do take part in a game (Castagna, Varley, Póvoas Araújo, & D'Ottavio, 2017; Oliveira et al., 2019), there was a proposal for a measurement of weekly load depending on the level of participation in the games that take place before the start of the training week.

Given the fact that the physical trainer suggested that players' fitness level could have an effect on players' accumulated TL and ML, it is worth mentioning that several studies (Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002; Jaspers et al., 2017) have found that players with an lower physical fitness showed an increase in their internal load. For this reason, players' initial physical fitness was evaluated with the aim of measuring the connection between accumulated TL or ML and a player's physical condition. Since soccer requires a series of cardiovascular demands because of the duration of games and, since acceleration phases are considered as a key component for players' performance when playing soccer (Anderson et al., 2016; Bradley et al., 2010; Malone et al., 2018; Mendiguchia et al., 2016; Weston, Siegler, Bahnert, McBrien, & Lovell, 2015), after having reached an agreement with the training staff and following the current literature, there was a suggestion of evaluating performance and mechanical variables over the acceleration phase, and cardiovascular performance variables. In addition, the evaluation of players' physical state would enable the comparison among players in the same competitive level.

Inasmuch as matches are the sessions that require the highest work load of the week (Castagna et al., 2017; Fessi et al., 2016; Ispirlidis et al., 2008; Rampinini et al., 2011), trainers suggested the ML quantification with three objectives in mind: a) assessing ML in relation to the specific position of each player in the soccer field (Barrett et al., 2018; Bush, Barnes, Archer, Hogg, & Bradley, 2015; Owen et al., 2016), b) measuring the ML in order to adapt recovery sessions as well as the pre-game session in relation to the PE of each player, hoping to achieve the best possible recovery (Clemente et al., 2017; Gaudino et al., 2015; Loturco et al., 2016) and c) assessing the ML in order to distribute the loads of week to prepare players for the following games (Los Arcos, Mendez-Villanueva, & Martínez-Santos, 2017; Malone et al., 2015; Thorpe et al., 2015). Furthermore, coaches wanted to know how the load varied between matches, an aspect which has also been demonstrated as relevant for this type of scientific research (Carling, Bradley, McCall, & Dupont, 2016). Thus, it is important to assess the variability of ML since several studies have shown that it is high. For instance, Gregson et al. (2010) showed some match-to-match variation in external ML (e.g., THSR, CV = 17.7±6.8%; HSR, CV = 16.2±6.4% and TSD, CV = 30.8±11.2%) and, nonetheless, different researchers, who systematically analysed in-season match-to-match variability through internal ML, found contradictory results (Los Arcos et al., 2016; Weston, Siegler, Bahnert, McBrien, & Lovell, 2015).

Apart from the regular competition, professional soccer teams from the Spanish LFP compete at the King's Cup as well. Therefore, trainers expressed their concern on the usefulness to assess players' load in those weeks when more than one game took place. Recent studies carried out with players who played in different competitions at the same time (Mohr et al., 2016; Varley, Di Salvo, Modonutti, Gregson, & Mendez-

Villanueva, 2017) showed, through different quantification methods, that values related to different aspects of players' load were altered. For instance, Varley et al. (2017) outlined the fact that players who played all group stage matches had a small increase in sprint distance from match 1 to match 2 and a small decrease in total distance from match 2 to match 3; However, for all other movement categories (i.e. walking, jogging, running and high-speed running) the differences between matches were unclear.

Bearing in mind the issues raised by the coaching staff, all the practical concerns and aiming at providing a greater understanding in the field of soccer studies, a research involving a professional soccer team from the Second Division was carried out.

### *Subchapter 1.2. Soccer match and training*

Soccer is a collaboration-opposition sport (collective duel) (Parlebas, 2001), that is, a special social system (Araújo & Davids, 2016; Parlebas, 2001), that confronts two teams of 11 players in an oriented space. Thus, soccer players are required to constantly adapt to the uncertain due to the presence of teammates and, especially, the opponents (Parlebas, 2001) and, as consequence, they must respond to an intermittent physical and physiological effort during, at least, 90 min (Los Arcos et al., 2014; Stølen, Chamari, Castagna, & Wisløff, 2005). In order to be able to respond to these physical and physiological demands, soccer players require different physical qualities (muscle strength, power, speed, agility, endurance) (Kunrath, Cardoso, Nakamura, & Teoldo, 2018; Sevil Serrano, Práxedes Pizarro, García-González, Moreno Domínguez, & del Villar Álvarez, 2017).

In addition, due to the organization of the competition system, players should maintain their physical fitness during a long time (i.e. 9-10 months) to adequately respond, week after week throughout in-season period, to the physical-physiological demand of the competition. Due to these high physical and physiological demands, special attention has been paid in the scientific literature to quantification of the TL and ML at different times of the season (Oliveira et al., 2019; Ritchie, Hopkins, Buchheit, Cordy, & Bartlett, 2016; Stevens et al., 2017). Furthermore, in order to avoid injuries, observing changes in physical condition and developing a physical training program that can help avoiding muscle fatigue, it is necessary to quantify the physical load

(Gabbett & Domrow, 2007; Johnston, Black, Harrison, Murray, & Austin, 2018; Romagnoli et al., 2016).

### *Subchapter 1.3. ML and TL quantification methods*

In scientific literature, different methods to quantify ML or TL can be observed. The quantification of ML or TL is generally based on both external (i.e. distance, power output, numbers of repetitions of actions at different intensities) and internal (i.e. oxygen uptake, HR, blood lactate and RPE) indicators of effort (Buchheit, 2014), which are then computed with training or match time to derive compound TL or ML measures (e.g. training stress core using power output) (Skiba, 2006), training impulse using HR (Banister & Hamilton, 1985) and PE using RPE (Foster, 1998).

Concerning the EL, independently from its internal features, it always refers to the physical load required by all the tasks involved in soccer, including both training and matches. Regarding its quantification, in soccer, it may be mainly distinguished between: OMS (Andrzejewski et al., 2018; Dellal, Lago-Peñas, Rey, Chamari, & Orhant, 2015; Varley et al., 2017) and GPS (Malone et al., 2018; Oliveira et al., 2019; Tierney, Young, Clarke, & Duncan, 2016). In reference to IL, typically, two different methods are used in soccer to quantify the internal TL: HR (Campos-Vazquez et al., 2017; Malone et al., 2015; Thorpe et al., 2015) and PE (Barrett et al., 2018; Fessi & Moalla, 2018; McLaren et al., 2017).

### Subchapter 1.3.1. External load

As it was previously mentioned in the EL, there are mainly two quantification methods: OMS and GPS. It may therefore be viewed as an athlete's response to a physical stimulus. Thus, the external loads represent the physical work performed during the training session or match.

#### *1.3.1.1. OMS*

The OMS, taking as example systems such as Amisco or Prozone, are monitoring computing systems with multiple cameras whose goal is to quantify players' movements throughout the field with an external, objective and non-invasive method. They collect and analyze data in order to, later on, generate a series of data about players' physical and technical performance. Variables of total distance, distance covered, intensity categories and frequency of occurrence in different positions and for each activity, help the assessment of the responds given by the players at the end of the exercise. These variables are given through the semi-automatic system of monitorization just mentioned (Castellano, Álvarez-Pastor, & Bradley, 2014; Dellal et al., 2015).

Despite the fact that its validity and reliability of this kind of monitoring systems has been quantified to verify the process of data collection and precision (Bush et al., 2015; Carling, Bradley, Mccall, et al., 2016), this system holds several limitations. The affordability of this kind of system is restricted to just a few teams due to its high costs of installation. In addition, it is not possible to observe the variability between the data collected in matches and training sessions, as its use is exclusive of matches.

#### *1.3.1.2. GPS*

The GPS has enabled sports scientists to accurately measure external loads so far (Campos Vázquez, Castellano, Toscano-Bendala, & Owen, 2019; Casamichana, Castellano, Diaz, Gabbett, & Martin-Garcia, 2019; Malone et al., 2015; Tierney et al., 2016). In many cases, these methods of monitoring such as GPS technology, is not a possibility for every club because of the high initial cost of purchasing the system and the excessive amount of time involved in the data processing afterwards. As a result, the use of these methods is restricted to a few institutions with the financial means to afford the system and staff trained on how to use it and how to process the data. Furthermore, until just a few years ago (i.e. until 2015) the quantification of the workload in competitive matches through the GPS were impossible due to the prohibition of wearing HR and/or GPS devices during official matches in Spanish soccer. It is worth mentioning that, since 2016, the FIFA (Sparks, Coetzee, & Gabbett, 2017) has carried out a series of regulatory changes regarding the use of GPS devices in soccer, allowing its use nowadays.

The GPS technology provides quantitative information on the position, displacement, velocity and acceleration of field sport athletes. Thus, GPS technology has been extensively used to quantify the physical response in professional soccer teams (Malone et al., 2018; Tierney et al., 2016). So in this way, use of GPS technology permits measurement of player position, velocity, and movement patterns (Abbott, Brickley, & Smeeton, 2018; Oliveira et al., 2019). Moreover, it also measures the total distance (Abbott, Brickley, & Smeeton, 2018), the distance covered at different running intensities (Bowen, Gross, Gimpel, & Li, 2017), the highest speed reached (Tierney et al., 2016), acceleration and deceleration (Gaudino et al., 2013; Ritchie et al., 2016), CODA (Kenhead, Arley, & Weddle, 2016; Tierney et al., 2016), peak metabolic power (Casamichana et al., 2019; Soto, Nieto, Suarez, & Ortega, 2019) and load player load (Giménez, Leicht, & Gomez, 2019; Soto et al., 2019). Furthermore, GPS provides information in relation to the specific and positional physical response from the official competition matches to the training sessions. However, the large variability of descriptors used in different research studies and the fact that the technology used did not distinguish between the types of tackles, such as whether it is a multiple player tackle, or the position of contact to the player (i.e. subjective factors), mean some limitations for the current device (Austin & Kelly, 2014).

**Subchapter 1.3.2. Internal load**

When talking about IL, it basically refers to the physiological response on the "work" performed. As aforementioned, two different methods to quantify IL are used in soccer: HR (Campos-Vazquez et al., 2017; Malone et al., 2015; Thorpe et al., 2015) and PE (Barrett et al., 2018; Fessi & Moalla, 2018; McLaren et al., 2017). Furthermore, the IL is related to biochemical (physical and physiological) and biomechanical stress responses.

*1.3.2.1. HR*

One of the most representative methods used to quantify IL is the HR based method (Campos-Vazquez et al., 2017; Selmi et al., 2018). Consequently, attention is increasingly being given to the evaluation of monitoring tools that may indicate the general effort status and quantify the IL of soccer players. Through implementation of different indicators that include HR derived indices (Cummins, Orr, O'Connor, & West, 2013) and its relation to the calculated time that a player remains in different intensity zones according to its $HR_{max}$. All this is calculated in response to load and using different quantifications methods such as Stagno´s adaptation to team sport (Campos-Vazquez et al., 2017), Edwards´ TL (Clarke, Farthing, Norris, Arnold, & Lanovaz, 2013) and individualized training impulses (iTRIMP) (Cummins et al., 2013).

The HR is an accessible and direct method of measurement. It can be collected in different situations (before, during or after exercise sessions) in order to obtain data about the changes in the evolution of HR along the three phases (i.e. warm up, main body and stretches) of one session. Its analysis is developed from the simple to the complex (HR values and HR variability) in order to quantify the TL and ML (Buchheit, 2014). Although the progress in technologies has enabled us to perform an effective analysis of HR during soccer training (Manzi, Iellamo, Impellizzeri, D'Ottavio, & Castagna, 2009), the HR values during physical exercise was and remains regularly used (Buchheit, 2014) since it does not require of advanced HR measurement and, at the same time, it is one of the easiest methods (if not the easiest one) to record (Buchheit, 2014).

Nowadays, the HR has become a one of the most-widely used methods to assess exercise intensity in sports of prolonged periods of time, such as soccer. This objective method based on the direct lineal relationship between HR and $VO_{2max}$ variables (Buchheit, 2014; Djaoui et al., 2016; Malone et al., 2015) has extensively been extensively researched and documented for training and match sessions in soccer (Buchheit, 2014; Selmi et al., 2018; Suarez-Arrones et al., 2015). Although HR indices are used in soccer and may reflect the aerobic load, one of the most important limitations is that in intermittent sports where there are multiple short actions in intense periods of play and with a high neuromuscular factor, it may not fully reflect the real neuromuscular response of this sport (Buchheit, 2014; Léo Djaoui, Haddad, Chamari, & Dellal, 2017).

#### *1.3.2.2 PE*

An interesting alternative to the methods previously mentioned could be overall PE (Borg, 1982; Borg, 1962), that is, the subjective perception of the effort. This involves sensations from circulation and respiration organs, from the muscles, the skin or the joints as well as the perception of effort, fatigue, strain exertion, heat or pain (Borg, 1962). Thus, this construct should be understood as a gestalt that comprises the sensations from many parts of the body and several types of perceptions (Los Arcos, 2014, p. 70). The primary aim of the construct of PE was to determine the capacity of the physical workload created based on psychological variables and so present direct associations with regard to the perceptions subjects (Borg, 1962). Moreover, the same author and other researchers found high associations between the PE and some physiological variables during several cycloergometer and treadmill exercises (Borg, 1970; Borg, 1962, 1973; Ekblom & Goldbarg, 1971; Robertson et al., 2004). Thus, the use of the PE as indicator of the intensity of physical exercise during several works in cycloergometer and treadmill was suggested. In addition, it enabled direct comparisons among subjects with respect to their perceptions (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004).

Several years later, the American researcher Carl. Foster was the first in suggesting the assessment of training session as a whole based on the overall PE to monitor in a simple way the internal TL of several sport modalities (Foster et al., 1995). The "session" RPE was multiplied by the total duration of training (in minutes) to create a training impulse score, which is referred to as TL. So, Foster et al. (1995) felt that the training "session" RPE method provided approximately the same information regarding the relative training intensity as the method of Banister et al. (1986) which relies on continuous measures of HR. Using the 0-10 scale (Foster et al., 2001), a modified version of the CR10 of (Borg, 1982), thirty minutes following the completion of each exercise bout, the subject was shown the RPE scale (category ratio 0-10) with verbal anchors and asked to provide a rating of the overall difficulty of the exercise bout, the session RPE. Primarily by focusing on the verbal anchors where *rest*, *very very easy*, *easy*, *moderate*, *somewhat hard*, *hard*, *very hard* and *maximal* match with 0, 1, 2, 3, 4, 5, 7 and 10 numerical rating and at the same time associated with the RPE scale while responding to the simple question ‘‘How was your workout?’’

| *Rating* | *Descriptor* |
|---|---|
| 0 | Rest |
| 1 | Very, Very Easy |
| 2 | Easy |
| 3 | Moderate |
| 4 | Somewhat Hard |
| 5 | Hard |
| 6 | - |
| 7 | Very Hard |
| 8 | - |
| 9 | - |
| 10 | Maximal |

**Figure 1**. 0-10 scale of Foster et al (2001)

Since Foster et al. (1995) suggested the quantification of the TL by the PE, PE-based TL has been widely used to quantify TL in team sports (Bartlett et al., 2017; Haddad, Stylianides, Djaoui, Dellal, & Chamari, 2017; Mujika, 2017). This method stands out for its versatility, easy use and low-cost option (Borg, 1982) for assessment of TL and ML. Moreover, its validity has been shown in several team sports (Carling, Bradley, McCall, & Dupont, 2016; Kempton et al., 2015; McLaren, Weston, Smith, Cramb, & Portas, 2015; Mclaren et al., 2018) and specifically in soccer (Bush et al., 2015; Djaoui et al., 2017; Gregson, Drust, Atkinson, & Salvo, 2010). For these reasons, PE-based TL has also been extensively used in professional soccer (Abbott, Brickley, & Smeeton, 2018; Carling, Bradley, Mccall, & Dupont, 2016; Clemente et al., 2017; Los Arcos et al., 2017).

According to the construct of PE mentioned so far, this is made up from a series of sensations from muscles, skin, and joints, together with the kinds of perceptions belonging to strength, resistance, effort and fatigue (Borg, 1962). Thus, at this point, we could designate two different methods of PE assessment: the overall PE and the differential PE. On the one hand, the overall PE is formed by the set of body sensations at any given time of exercise, provided by global and subjective assessment, which refers to different kinds of perceptions like effort, intensity or fatigue, depending on properties of physical exercise performed (Haddad et al., 2017; Singh, Foster, Tod, & McGuigan, 2007). The final result consists of just one value of sensorial information for every part of human body. On the other hand, it should be taken into consideration that this overall PE can also be deconstructed. So, it is possible to obtain the dRPE (i.e., respiratory and muscular PEs), in order to provide additional information from that obtained by a single measure (Arcos et al., 2014; Gil-Rey et al., 2015; Los Arcos et al., 2015; Mclaren et al., 2016; Weston et al., 2015). These measures provide a more detailed quantification of exercise intensity and IL during training modes commonplace to team sports (McLaren et al., 2017) and recently, some substantial associations have been found between internal (i.e. respiratory and muscular PE TL) and external measures of load and intensity during training and competition in professional soccer players (Mclaren et al., 2018). The results of this (Mclaren et al., 2018) and many other researches (Barrett, McLaren, Spears, Ward, & Weston, 2018; Bartlett et al., 2017; McLaren et al., 2017) suggest that dRPE between respiratory and muscular could provide additional information for quantification of exercise intensity and internal load to team sports like soccer, so it makes perfectly suitable to use of this method in soccer.

Within the subjective assessment of internal load, PE was the most suitable method for the soccer team, as it that was transmitted by the physical coach as well, since this one was presented as simple, cheap, versatile and suitable to be used when assessing competition and training.

As described above, when assessing dRPE, players responded to two simple questions (always asked in the same order) on a single evaluation sheet: How hard was your session on your chest? How hard was your session on your legs? Players were allowed to mark a plus sign (interpreted as 0.5 point) alongside the integer value (Arcos et al. 2014; Los Arcos et al. 2015, 2016). Each player completed the 0–10 scale randomly without other players being present and without knowing the values of other participants. Players were introduced to the method beforehand so that it would be familiar to them prior to the quantification (Borg, 1998). Another important aspect to bear in mind was the time allotted to complete their answers. In general, in relation to the appropriate time to declared PE, Los Arcos et al., (2015) requested the dRPE 10 minutes after completing each training and match session. By doing this, these authors obtained the same results than others such as Foster et al., (2001) who asked about PE, in different sports 30 min after training or match sessions, in order to avoid the impact of last part of session or match (Los Arcos et al., 2015). It is important to follow this data gathering protocol to preserve the standardization of the information (Borg, 1962).

After initial measurement of how hard the training or match work is, both respiratory and muscular perceived TLs (sRPEres-TL and sRPEmus-TL) are calculated, multiplying the sRPE value by the duration of the training session or match (Arcos et al., 2014; Los Arcos et al., 2015) and the TL or ML in AU is obtained. So, for these and other reasons mentioned, the PE is presented as a versatile, easy-to-use and as a low-cost option (Borg, 1982) which has been previously validated in soccer (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004; Scott, Lockie, Knight, Clark, & Janse de Jonge, 2013).

### *Subchapter 1.4. ML in soccer*

In soccer, ML typically represents the highest TL of the week (Arcos et al., 2014; Barrett et al., 2018; Los Arcos et al., 2017). Several research which has analyzed the external ML (total distance, distance covered at different intensities, acceleration/decelerations, changes of direction, player load and peak metabolic power) using GPS technology (Abbott, Brickley, & Smeeton, 2018; Campos Vázquez et al., 2019; Casamichana et al., 2019; Castagna et al., 2017; Malone et al., 2015) while other researchers have analyzed internal ML through HR derived measurements such as Edward's ML and Stagno training impulses ($TRIMP_{MOD}$) and also, through sRPE-ML (Campos-Vazquez et al., 2017; Jaspers et al., 2017). In recent years, sRPE-ML has increasingly been used to measure internal load in soccer matches (Barrett et al., 2018; Los Arcos et al., 2016).

It has been described that professional soccer players typically cover a distance of 10-14 km per match (Anderson et al., 2016; Castagna et al., 2017; Whitehead et al., 2018). In a recent study, Padrón-Cabo et al. (2019) showed that regardless of players' position, ST players covered a distance of 80.5 ± 6.7 m at low intensity, 20.8 ± 5.6 m at medium intensity, 2.5 ± 1.0 m at high intensity, 2.5 ± 1.4 m when sprinting, 5.1 ± 2.1 m at high intensity running and 8.9 ± 0.4 m at maximal running speed. Other authors showed that players covered a total distance of 10927 ± 619 m, of which 1614 ± 320 m at running (14.4 – 19.8 $km \cdot h^{-1}$) and 738 ± 244 m at HSR (>19.8 $km \cdot h^{-1}$) in a soccer match (Stevens et al., 2017). Simultaneously, players are required to develop a large amount of short actions throughout that time (Sarmento et al., 2018). Accordingly, Stevens et al. (2017) showed the number of medium (1.5 – 3.0 $m \cdot s^{-2}$) and high (> 3.0 $m \cdot s^{-2}$) acceleration and medium (-1.5 to -3.0 $m \cdot s^{-2}$) and high (< -3.0 $m \cdot s^{-2}$) deceleration where players performed 165 ± 25 medium and 61 ± 14 high accelerations, and 111 ± 19 medium and 58 ± 14 high decelerations in match. Russell et al. (2016) highlighted that the number of high-intensity impacts remained unchanged throughout the match-play ($p > 0.05$). Thus, these findings could indicate that high-intensity actions and markers of acceleration and deceleration capacity are reduced in the last 15 minutes of the normal duration of match-play. Following these lines, Bradley et al. (2010) showed that the number of discrete acceleration (>2.5 $m \cdot s^{-2}$) efforts remained consistent across halves and between the first and last 15 minutes of elite match-play. Moreover, matches are, for ST, the most demanding physical/physiological sessions of the week (Anderson et al., 2016; Arcos et al., 2014; Los Arcos et al., 2017).

Match analyses of the physiological demand have revealed that the game is characterized by standing episodes with an average game intensity ranging from 80 to 90% of $HR_{max}$ (Dellal et al., 2012). Rebelo et al. (2014) showed HR during match play and presented that mean HR during the match was 168 ± 12 bpm (range: 140−187). Furthermore, players spent 40% ± 11% (14−67), 23% ± 9% (5−38), and 10% ± 8% (0−28) of the playing time with the HR between 80%−90%, 90%−95%, and >95% of the maximal HR, respectively. In relation to the Edward's-ML, Campos-Vazquez et al. (2017) showed 1,740.5 ± 382.0 AU during friendly matches for professional soccer players that participated in the preseason of Second Division Spanish league, being substantially lower than that of the training sessions (3,123.9 ± 427,7 AU). Furthermore, added that the average value for the Edward's-ML for friendly matches was 280.9 ± 40.5 AU throughout four weeks, being substantially higher than that of the training sessions (148,8 ± 46,4 AU). In a recent study, Campos-Vázquez et al. (2019) obtained 356.9 ± 58.2 AU in friendly matches for TRIMP values calculated by Edward's indicator. Also, Rabbani et al. (2019) showed the mean ± SD values of relative

Edward's TRIMP (166.8 ± 23.2 AU) in data collected during the mid-season phase after 15 official matches.

The ML measurement through RPE, just as the results obtained via the used of other methods (Dellal et al., 2012; Rebelo et al., 2014), showed that the matches analyzed in professional soccer players who competed in the AFL and the VFL provided the greatest load and intensity of all training sessions at 570 ± 240 ML (AU) for pre-season and 980 ± 190 ML (AU) for in-season (Ritchie et al., 2016). Furthermore, the ML was characterized by the high-intensity nature and increased load of matches (~ 900 RPE load units per match) (Ritchie et al., 2016). Authors as Los Arcos et al. (2016) found that professional soccer Spanish players, with an average number of 23 matches per player, rated the entire official match as "very hard", where sRPEres = 6.7 ± 1.3 and sRPEmus = 6.9 ± 1.6, being respiratory and muscular perceived TL of 630 ± 126 and 655 ± 150 AU. Fessi & Moalla (2018) collected data from 52 matches and found that player RPE was significantly higher by a very large magnitude in a loss compared with a draw (1.78 ± 0.19, $p = 0.04$; ES = 2.3) and a win (2.08 ± 0.15, $p < 0.01$; ES = 2.8). Likewise, player RPE was significantly higher by a small magnitude in a draw compared with a win (0.30 ± 0.18, $p < 0.01$; ES = 0.4).

### Subchapter 1.4.1. Contextual variables that affect to the ML

In relation to the contextual variables that affect ML, several studies have already provided plenty of results according to variables of match location (home vs. away), score (win, draw and lose), opponent level (top, medium and bottom) and match half (first vs. second) (Barrett et al., 2018; Brito, Hertzog, & Nassis, 2016; Castellano, Blanco-Villaseñor, & Álvarez, 2011). These variables are a key factor in match analysis in order to determine the probability of causal match-to-match changes in physical performance and to detect team or individual fitness and or technical-tactical differences (Castagna et al., 2017). For instance, Barrett et al. (2018) showed substantially higher RPE-L scores in top (72 ± 20 AU) than middle (65 ± 20 AU) and bottom (63 ± 18 AU) using an estimated marginal mean ± SD derived from the mixed linear model for the fixed effect (match opposition standard). In a recent study, Johnston et al. (2018) and Lazarus et al. (2018) showed that according to player quality and experience, increased experience has a small, positive effect on match performance and match outcome (Johnston et al., 2018; Lazarus, Hopkins, Stewart, & Aughey, 2018). Furthermore, it should be taken into account that professional soccer players participate in successive matches throughout a season, so it is possible that fluctuations in external ML in reference to background variables (match location, opponent level, match half) (Bush et al., 2015; Varley et al., 2017), changes in physical fitness of soccer players (Gregson et al., 2010), environmental conditions (Ekblom, 1986), playing style, tactical organization or team rotation (Carling, McCall, Le Gall, & Dupont, 2015) will lead us to find contradictions among several studies. In addition, it was found that different contextual variables differed considerably between playing positions (Bush et al., 2015; Carling, Bradley, Mccall, et al., 2016). Using a computerized multiple-camera tracking system Bush et al. (2015) shown that CD, FB and WF demonstrated moderate increases in high-intensity running distance covered with ball position (CD: 114 ± 61 vs. 193 ± 86 m, $p < 0.001$, ES = 1.1; FB: 355 ± 159 vs. 503 ± 181 m, $p < 0.001$, ES = 0.9; wide midfielders: 591 ± 178 vs. 710 ± 171 m, p < 0.01, ES = 0.8). In contrast, CMs and Ss showed small increases ($p < 0.05$, ES = 0.5 and 0.6). Regarding the HR, Suarez-Arrones et al. (2015) shown that the average HR recorded during the half was 87.1% $HR_{max}$ with significant differences between playing positions. So, WF recorded a significantly smaller average HR than any other group of playing position. Thus, it seems to be of great importance to evaluate the amount of match respiratory and muscular exertions according to playing positions in professional soccer players.

### Subchapter 1.4.2. Match to match load and variability

A relevant characteristic of the ML is its high variability (Weston et al., 2015). The ML and their variability between matches has been observed in several studies with professional soccer players (Bush, Archer, Hogg, & Bradley, 2015; Carling, Bradley, Mccall, & Dupont, 2016; Gregson, Drust, Atkinson, & Salvo, 2010b; McLaren, Weston, Smith, Cramb, & Portas, 2015; Varley et al., 2017). So, the ML has showed controversy in all of them through different methods of external quantification (GPS, OMS). For instance, a match-to-match variation has been observed in external ML (i.e., THSR (average running speed >19.8 km/h over a 0.5 s time interval), CV = 17.7 ± 6.8%; HSR (average running speed from 19.8 km/h to 25.2 km/h over a 0.5 s time interval), CV = 16.2 ± 6.4%; TSD (average running speed >25.2 km/h over a 0.5 s time interval), CV = 30.8 ± 11.2%) (Gregson et al., 2010). Authors such as Carling et al. (2016) showed that match-to-match variability were higher for TSD while compared to HSR and THSR (37.1% vs 18.1% vs 19.8%, respectively). Furthermore, an increase in individual and collective variability in THSR was observed in relation to the distance covered in two different situations; when the players' team was in ball possession (collective range: 16.6 – 50.5%; 31.5% for all players) and when they were not in ball possession (range: 18.1 – 45.6%; 26.1% for all players). Simultaneously, Castagna et al. (2017) found that absolute inter-teams variability (i.e. CV%) were below 5% for TD covered, and AMP showing high measurement stability for these global match-activity variables. Bush et al. (2015) described a match-to-match variability from 10.7% to 32.3% reported for high-intensity-running variables of velocity covered during a match in professional soccer players of the English Premier League. However, in reference to ML and their variability observed with methods of internal quantification, only a few studies have assessed the variability in matches through different methods of internal quantification (Barrett et al., 2018; Weston et al., 2015). Furthermore, these previous studies did not analyze the dRPE-ML over a period of two or three official matches within the same week and did not take into account the matches types (i.e. matches in regular league or other official competitions). Likewise, there are very few studies that have assessed match-to-match dRPE variability of professional soccer players according to their playing position (Barrett et al., 2018). Thus, these results could add new and interesting information to performance knowledge of the soccer players in match.

Furthermore, not much research has systematically analyzed match-to-match variability for perceived ML in a season, and those done showed controversial results (Los Arcos et al., 2016; Weston et al., 2015). For instance, whereas overall sRPE match-to-match variability (i.e., quantified by means of the CV) in young soccer players was lower than 5% (Wrigley, Drust, Stratton, Scott, & Gregson, 2012), a study with Australian soccer players found dRPE variability between matches over 129 consecutive matches (i.e. matches per player = 5.0 ± 1.6) during the AFL season to average 12.4 ± 1.5% for RPE-B, and 11.5 ± 1.4% for RPE-L (Weston et al., 2015). Thus, even though there are plenty of studies in relation to the ML and the variability in matches quantified through both internal and external methods, there are still many questions left to be resolved.

### Subchapter 1.4.3. Influence of one or several matches in soccer

Roughly speaking, it is know that it is important to allow sufficient recovery time between training sessions and competitions. An imbalance between TL/ML and recovery may, over extended periods of time contribute to potentially long-term debilitating effects associated with overtraining (Jaspers et al., 2017). It is well known that while some parameters are completely recovered (e.g. hormonal and technical), Silva et al. (2018) showed that a period of 72 h post-match play is not long enough to fully restore homeostatic balance (e.g. muscle damage, physical and well-being status).

In another study divided in micro-cycles of one-, two- and three-game per week, Oliveira et al., (2019) pointed out significant differences in training intensity for zone 1 between M5 and M3 (4010.2 ± 103.5 and 4507.6 ± 133.0 m, respectively); a significant difference in training intensity for zone 3 between M4 and M2 (686.1 ± 42.8 and 801.2 ± 61.2 m, respectively); and a significant difference in the duration of the training sessions and matches between M5 and M2 (69.2 ± 2.1 and 79.6 ± 2.3 m) and M1 and M2 (69.7 ± 1.0 and 79.6 ± 2.3 m) where zones are: zone 1 (0 – 10.9 Km/h), zone 2 (11 – 13.9 Km/h), zone 3 (14 – 18.9 Km /h), zone 4 (19 – 23.9 Km/h) and zone 5 (>24 Km/h). The fact that the professional team must participate in several competitions at the same time, means that professional soccer players must play up to 3 consecutive soccer matches within a week (Nimmo & Ekblom, 2007) in addition to several training sessions, with only 3-4 days of recovery (i.e. 72 h approx.) allowed between successive matches. So, as previously mentioned, this time of recovery may be insufficient to restore normal homeostasis (Nimmo & Ekblom, 2007; Silva et al., 2018) and neuromuscular performance (Andersson, Ekblom, & Krustrup, 2008; Fatouros et al., 2010; Mohr et al., 2016). Silva et al. (2018) mentioned that the extent of the recovery period post-soccer match could not consist of a 'one size fits all approach'. Furthermore, the authors showed that the 'real match' (11 vs. 11 format) is likely to induce greater magnitudes of perceptual (DOMS) and biochemical alterations (e.g. muscle damage), while neuromuscular alterations were essentially similar. Actually, the optimal total time of recovery for a professional soccer player is still unknown.

On the one hand, taking previous and future matches as a reference, in weeks when only one match was held, professional soccer coaches design recovery sessions for starting players (i.e. players who participate in the match for at least 45 min) at the beginning of the week (Andersson, Ekblom, & Krustrup, 2008; Fatouros et al., 2010; Mohr et al., 2016), planning training activities to attain the highest weekly TL in the middle of the week (Nedelec et al., 2014) and reducing physiological and physical demands in training sessions prior to a match (Los Arcos et al., 2017; Malone et al., 2015; Thorpe et al., 2015), in order to prepare players for the competition and avoid pre-match fatigue. On the other hand, during weeks when two matches are played, the internal TL of training sessions is reduced in comparison to weeks with one match, signaling the importance that recovery strategies have in the former (Clemente et al., 2017) for players to be at their top physical shape in each match. In relation to accumulated fatigue, reductions have been observed in external ML by players required to participate in successive matches with less than 72 h in between during national competition, for instance 3 matches in 5 days (Clemente et al., 2017). In the same point of view, Clemente et al. (2017) observed that elite male soccer players have a deficit for high intensity running distance in match 2 (7%, $p < 0.05$) and match 3 (14%, $p < 0.05$) compared to match 1 (i.e. being the matches played in the same week). Therefore, the ML seems to determine the weekly distribution of TL (Odetoyinbo, Wooster, & Lane, 2007) and a match may always be affected by the previous match. Even though the influence of playing several matches in the same week has been analyzed through objective methods, few studies have evaluated it through RPE methods (Oliveira et al., 2019). Hence, it is still necessary to analyze this aspect.

### *Subchapter 1.5. TL in soccer*

In addition to the ML, it is important to quantify TL. This has been evaluated both through external (GPS and OMS) and internal (HR and PE) quantification methods in professional soccer players. These training sessions prepared players to face the most important session and higher load of the week (match) (Barrett et al., 2018; Los Arcos et al., 2017). Thus, it is important to consider the periodization of training through the TL quantification in order to handle the accumulated TL (Castillo, Weston, McLaren, Cámara, & Yanci, 2017; Clemente, Rabbani, Conte, & Castillo, 2019; Jaspers et al., 2017) and, at the same time, to assure enough recovery time after matches (Rampinini et al., 2011). This is possible to be observed in recent researches (Jeong, Reilly, Morton, Bae, & Drust, 2011; Malone et al., 2015).

Due to the need of competing every week, this temporal unit has turned into the periodization unit of professional soccer coaches (Arcos et al., 2014; Malone et al., 2015), bearing in mind that during that time, firstly, players must be available and secondly, they should therefore be able to respond to the physical and physiological efforts required in the match. Thus, the physical-physiological demand of the training and match sessions must be quantified in view of three objectives: a) to reduce unintentional and non-traumatic injuries (Al Attar, Soomro, Sinclair, Pappas, & Sanders, 2017; Malone et al., 2018; Silva et al., 2018), b) to ensure (or improve) the sufficient level of physical fitness to respond to the various sorts of physical and physiological demands of training and match (Eliakim, Doron, Meckel, Nemet, & Eliakim, 2018; Jaspers et al., 2017; Los Arcos et al., 2017), and c) to ensure recovery from the previous match and prevent pre-match fatigue in each competition week (Clemente et al., 2017; Silva et al., 2018).

### Subchapter 1.5.1. TL throughout the season

The overall physiological loads associated with pre-season phase are higher than those observed in the in-season, even though the match-to-match variability could attenuate the relevance of these findings (Los Arcos et al., 2017; Malone et al., 2015). In a recent study, Malone et al. (2015) aimed at quantifying the TL employed by an elite professional soccer team across an annual season (i.e. preseason and in-season), it's shown that $\%HR_{max}$ was significantly lower in week 7 than in either week 24 (6.9 [4.6 – 9.2], ES = 1.06 [0.71 – 1.41], moderate) or week 39 (4.5 [2.2 – 6.9], ES = 0.69 [0.34 – 1.05], moderate). Furthermore, MD-1 displayed significantly lower values than MD-2 in high-speed distance, total distance, average speed, $\%HR_{max}$, sRPE and at the same time, MD-5 displayed higher values than MD-1 for duration, total distance, high-speed distance and RPE load. Los Arcos et al. (2017) found substantial within-group (i.e. ST and N-S) differences between the accumulated sRPEres-TL and sRPEmus-TL between training days of the competitive period. Furthermore, the weekly perceived TL variation across in-season blocks was trivial-small (ES = 0.17 - 0.41) for both ST and N-S, except between Block 2 and Block 3, where a small-moderate TL decrease was found (ES = -0.56 – -1.20) (Los Arcos et al., 2017). Other authors in a study carried out in a top European team that played in a UEFA Champions League, showed significant difference in training intensity of zone 1 between the microcycle 5 and microcycle 3 (4010.2 ± 103.5 vs 4507.6 ± 133.0 m, respectively) (Oliveira et al., 2019). Moreover, there was also a significant difference in training intensity of zone 3 between M4 and M2 (686.1 ± 42.8 vs 801.2 ± 61.2 m, respectively), as well as a difference in duration of training sessions and matches between M5 and M2 (69.2 ± 2.1 vs 79.6 ± 2.3 min, respectively) and M1 and M2 (69.7 ± 1.0 vs 79.6 ± 2.3 min, respectively) (Oliveira et al., 2019).

For instance, several studies found that, in professional soccer players, the week average sRPEres-TL and sRPEmus-TL was greater in the pre-season. Meanwhile, the session-average sRPEres-TL and sRPEmus-TL was approximately similar throughout the weeks (Mclaren et al., 2016; McLaren et al., 2017). Similarly, Mclaren et al. (2016) and McLaren et al. (2017) showed the pattern of the average sRPEres-TL and sRPEmus-TL profiles during the most typical weekly micro-cycle that comprised 1 match on week, being the highest scores of the week on the match day in the players playing > 70 min per match. Other authors such as McLaren et al. (2017) researched the application of dRPE to team-sport training and observed that between-session differences in dRPE scores ranged from very likely trivial to most likely extremely large and within-session differences amongst dRPE scores ranged from unclear to most likely very large. These studies revealed that TL variables demonstrated limited relevant variation across both the preseason and in-season phases. Moreover, when analyzing TL in respect to number of days before a match, it was found that TL remained similar across all days with the exception of MD-1, when the load was significantly reduced.

### Subchapter 1.5.2. TL in shorter period of time (week)

Despite the fact that some studies have described TL distribution along the training week, soccer team periodization strategies are still relatively unknown (Anderson et al., 2016; Clemente, Rabbani, Conte, & Castillo, 2019; Los Arcos et al., 2017; Loturco et al., 2016; Malone et al., 2015). Recently, several studies have systematically attempted to describe the weekly TL distribution across the length of the between-match microcycle (Los Arcos et al., 2017) and the different periods of the season (Anderson et al., 2016; Los Arcos et al., 2017; Malone et al., 2015). Los Arcos et al. (2017) showed trivial differences within-group (i.e., ST and N-S) between the accumulated sRPEres-TL and sRPEmus-TL from each training day and substantial TL differences (ES = small–very likely) between training days for both groups. Thereby, the TL pattern showed a progressive increase until MD-3 with a subsequent decrease until MD-1.

As stated above, suggested that the monotony of TL is related to the in-season period (Mclaren et al., 2016; McLaren et al., 2017). In addition, the results indicated that the daily TL was steady across most training days of the week in the in-season period, except for the day before a match, when the load was significantly reduced (Los Arcos et al., 2017; Oliveira et al., 2019). Furthermore, professional soccer players nowadays participate in more matches per week (i.e. league, cup, UEFA competitions), and thus more matches per season. As a result, physical trainers do not seem to have enough training days to prepare their players. This fact can make it difficult for coaches to manage the TL and avoid accumulated fatigue, while ensuring that players remain at an optimal level of physical fitness (Oliveira et al., 2019). Thus, given the fact that week duration and the number of matches varies throughout the season, it may be relevant to measure and assess week load in professional soccer players, with the aim of finding out whether week load changes according to how long the week lasts.

### *Subchapter 1.6. Influence of physical fitness performance in TL or ML*

Soccer players must be able to respond to several types of demand (i.e. decisional, affective, social, physical-physiological demands) (Parlebas, 2001) during the training sessions and, specially, during the match. First of all, their level of physical fitness should be the suitable one to respond to the various sorts of physical and physiological demands of training and match. Given the fact that TL seems to have an influence, at least in part, in players' physical condition level (Bowen et al., 2017; Delecroix, McCall, Dawson, Berthoin, & Dupont, 2018; Raya-González, Nakamura, Castillo, Yanci, & Fanchini, 2019), the quantification of TL is mainly necessary due to the large number of influencing factors in training and match sessions. This last fact very frequently, means a challenge for coaches' ability to ensure an appropriate balance between training stimuli and recovery (Campos-Vazquez et al., 2015).

On the whole, different researches have assessed the relationship between longitudinal changes in TL and physical fitness performance simultaneously to aerobic fitness variables (Campos-Vazquez et al., 2015) and neuromuscular factors (i.e. strength, power, speed) (Los Arcos, Martínez-Santos, Yanci, Mendiguchia, & Méndez-

Villanueva, 2015) which are heavily taxed during matches and training sessions (Rampinini et al., 2011; Robineau, Jouaux, Lacroix, & Babault, 2012). This has led to the fact that are limited the studies (Da Silva, Guglielmo, & Bishop, 2010; Jaspers et al., 2017; Mclaren et al., 2018) that have examined the relationship between single load indicators and changes in physical fitness, injury, or illness. Tanking into account that soccer players suffer few changes according to their physical condition throughout in-season period (Los Arcos & Martins, 2018), this fact leads us to think that a similar physical state is developed though the player to respond to a match-to-match physical demand very changeable, and maybe higher at the end in-season.

On the other hand, several researches carried out with professional soccer players evaluated the ML and TL (Jaspers et al., 2017; Malone et al., 2015). This studies showed that the accumulated load throughout different weeks could be able to decide the physiological adaptations of players (Malone et al., 2015) and affect to the different fatigue levels or risk of physical injury (Malone et al., 2018). Recently, high weekly load has been observed as an important factor to increase the injury risk (Bowen et al., 2017). Accordingly, several researches (Gastin, Meyer, Huntsman, & Cook, 2015; Jaspers et al., 2017) have analyzed whether the initial physical fitness of soccer players could be associated with the TL and ML and risk of injury. In this connection, Gastin et al. (2015) showed substantial associations between low physical fitness and higher injury risk in professional Australian soccer players. Although the associations between initial physical fitness and TL and ML have been analyzed through objective methods (Gastin et al., 2015; Jaspers et al., 2017), to our knowledge, previously no studies have examined the associations between the initial physical fitness and the dRPE TL or dRPE ML in professional soccer players.

### *Subchapter 1.7. References*

Abbott, W., Brickley, G., & Smeeton, N. J. (2018). Positional differences in GPS outputs and perceived exertion during soccer training games and competition. *Journal of Strength and Conditioning Research*, *32*(11), 3222–3231.

Abbott, W., Brickley, G., Smeeton, N. J., & Mills, S. (2018). Individualizing acceleration in English Premier League academy soccer players. *Journal of Strength and Conditioning Research*, *32*(12), 3503–3510.

Abbott, W., Brickley, G., & Smeeton, N. J. (2018). An individual approach to monitoring locomotive training load in English Premier League academy soccer players. *International Journal of Sports Science and Coaching*, *13*(3), 1–8.

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 Science*, *34*(24), 2205–2214.

Al Attar, W. S. A., Soomro, N., Sinclair, P. J., Pappas, E., & Sanders, R. H. (2017). Effect of injury prevention programs that include the nordic hamstring exercise on hamstring injury rates in soccer players: A systematic review and meta-analysis. *Sports Medicine*, *47*(5), 907–916.

Andersson, H., Ekblom, B., & Krustrup, P. (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *Journal of Sports Sciences*, *26*(2), 113–122.

Andersson, H., Raastad, T., Nilsson, J., Paulsen, G., Garthe, I., & Kadi, F. (2008). Neuromuscular fatigue and recovery in elite female soccer: Effects of active recovery. *Medicine and Science in Sports and Exercise*, *40*(2), 372–380.

Andrzejewski, M., Pluta, B., Konefał, M., Konarski, J., Chmura, J., & Chmura, P. (2018). Activity profile in elite Polish soccer players. *Research in Sports Medicine*, *14*, 1–12.

Araújo, D., & Davids, K. (2016). Team synergies in sport: Theory and measures. *Frontiers in Physiology*, *21*(7), 1449.

Atkinson, G., & Nevill, A. (1998). Statistical methods for assssing measurement error (Reliability) in variables relevant to sports medicine. *Sports Medicine*, *26*(4), 217–238.

Austin, D., & Kelly, S. (2014). Professional rugby league positional match-play analysis through the use of global positioning system. *Journal of Strength and Conditioning Research*, *28*(1), 187–193.

Azcárate, U., Yanci, J., & Arcos, A. L. (2018). Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players ’ perceived training load. *Science and Medicine in Football*, *2*(1), 23–28.

Banister, E. W., & Hamilton, C. L. (1985). Variations in iron status with fatigue modelled from training in female distance runners. *European Journal of Applied Physiology and Occupational Physiology*, *54*, 16–23.

Barrett, S., McLaren, S., Spears, I., Ward, P., & Weston, M. (2018). The influence of playing position and contextual factors on soccer players’ match differential ratings of perceived exertion: A preliminary investigation. *Sports*, *6*(1), 13.

Bartlett, J. D., Pitchford, N., Thornton, H. R., Weston, M., Ritchie, D., O’Connor, F., & Juhari, F. (2017). The quantification of within-week session intensity, duration, and intensity distribution across a season in australian football using the session rating of perceived exertion method. *International Journal of Sports Physiology and Performance*, *13*(7), 940–946.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physilogy and Performance Sport*, *1*, 50–57.

Beato, M., Jamil, M., & Devereux, G. (2018). Reliability of internal and external load parameters in recreational football (soccer) for health. *Research in Sports Medicine*, *26*(2), 244–250.

Borg, G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*, *2*(2), 92–98.

Borg, G. (1998). *Borgs´s Perceived Exertion and pain scales*. Champaign, IL: Human Kinetics.

Borg, G. A. V. (1962). *Physical Performance and Perceived Exertion*. Lund.

Borg, G. A. (1973). Perceived exertion: a note on “history” and methods. *Medicine and Science in Sports*, *5*(2), 90–93.

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.

Bradley, P. S., Di Mascio, M., Peart, D., Wooster, B., Olsen, P., & Sheldon, B. (2010). High-Intensity activity profiles of elite soccer players at different performance levels. *Journal of Strength and Conditioning Research*, *24*(9), 2343–2351.

Buchheit, M., Simpson, B. M., & Mendez-Villanueva, A. (2012). Repeated high-speed activities during youth soccer games in relation to changes in maximal sprinting and aerobic speeds. *International Journal of Sports Medicine*, *34*(1), 40–48.

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

Bush, M. D., Archer, D. T., Hogg, R., & Bradley, P. S. (2015). Factors influencing physical and technical variability in the English Premier League. *International Journal of Sports Physiology and Performance*, *10*(7), 865–872.

Campos-Vazquez, Miguel A., Toscano-Bendala, F. J., Mora-Ferrera, J. C., & Suarez-Arrones, L. J. (2017). Relationship between internal load indicators and changes on intermittent performance after the preseason in professional soccer players. *Journal of Strength and Conditioning Research*, *31*(6), 1477–1485.

Campos-Vazquez, Miguel Angel, Mendez-Villanueva, A., Gonzalez-Jurado, J. A., León-Prados, J. A., Santalla, A., & Suarez-Arrones, L. (2015). Relationships between RPE- and HR-derived measures of internal training load in professional soccer players: A comparison of on-field integrated training sessions. *International Journal of Sports Physiology and Performance*, *10*(5), 587–592.

Carling, C., & Dupont, G. (2011). Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? *Journal of Sports Science*, *29*(1), 63–71.

Carling, C., McCall, A., Le Gall, F., & Dupont, G. (2015). What is the extent of exposure to periods of match congestion in professional soccer players? *Journal of Sports Science*, *33*(20), 2116–2124.

Carling, C., Bradley, P., 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.

Carling, C., McCall, A., Le Gall, F., & Dupont, G. (2015). The impact of in-season national team soccer play on injury and player availability in a professional club. *Journal of Sports Sciences*, *33*(17), 1751–1757.

Casamichana, D., & Castellano, J. (2014). Situational variables and distance covered during the FIFA Wold Cup South Africa 2010. *Revista Internacional de Medicina y Ciencias de La Actividad Física y Del Deporte*, *14*(56), 603–617.

Castagna, C., Impellizzeri, F., Chaouachi, A., & Manzi, V. (2013). Preseason variations in aerobic fitness and performance in elite-standard soccer players: A team study. *Journal of Strength and Conditioning Research*, *27*(11), 2959–2965.

Castagna, C., Varley, M., Póvoas Araújo, S. C., & D'Ottavio, S. (2017). The Evaluation of the match external load in soccer: Methods comparison. *International Journal of Sports Physiology and Performance*, *12*(4), 490–495.

Castellano, J., Blanco-Villaseñor, a., & Álvarez, D. (2011). Contextual variables and time-motion analysis in soccer. *International Journal of Sports Medicine*, *32*(6), 415–421.

Castellano, J., Álvarez-Pastor, D., & Bradley, P. S. (2014). Evaluation of research using computerised tracking systems (Amisco and Prozone) to analyse physical performance in elite soccer: a systematic review. *Sports Medicine*, *44*(5), 701–712.

Castillo, D., Los Arcos, A., & Martínez-Santos, R. (2018). Aerobic endurance performance does not determine the professional career of elite youth soccer players. *Journal of Sports Medicine Physiology Fitness*, *58*(4), 392–398.

Clemente, F. M., Sarmento, H., Rabbani, A., Van Der Linden, C. M. I. N., Kargarfard, M., & Costa, I. T. (2019). Variations of external load variables between medium- and large-sided soccer games in professional players. *Research in Sports Medicine*, *27*(1), 50–59.

Clemente, F., Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., & Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Journal Physiology and Behavior*, *28*(179), 262–267.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. *(Second ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.*

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

Da Silva, J. F., Guglielmo, L. G. A., & Bishop, D. (2010). Relationship between different measures of aerobic fitness and repeated-sprint ability in elite soccer players. *Journal of Strength and Conditioning Research*, *24*(8), 2115–2121.

Delecroix, B., McCall, A., Dawson, B., Berthoin, S., & Dupont, G. (2018). Workload monotony, strain and non-contact injury incidence in professional football players. *European Journal of Sport Science*, *18*(9), 1280–1287.

Dellal, A., Da Silva, C. D., Hill-Haas, S., Wong, D. P., Natali, A. J., De Lima, J. R., … Karim, C. (2012). Heart rate monitoring in soccer: Interest and limist during competitive match play and training, practical application. *Journal of Strength and Conditioning Research*, *26*(10), 2890–2906.

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.

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*(3), 205–212.

Djaoui, L., Diaz-Cidoncha, J., Hautier, C., & Dellal, A. (2016). Kinetic post-match fatigue in professional and youth soccer players during the competitive period. *Asian Journal of Sports Medicine*, *7*(1).

Djaoui, Léo, Haddad, M., Chamari, K., & Dellal, A. (2017). Monitoring training load and fatigue in soccer players with physiological markers. *Physiology and Behavior*, *181*, 86–94.

Draganidis, D., Chatzinikolaou, A., Avloniti, A., Barbero-Álvarez, J. C., Mohr, M., Malliou, P., … Fatouros, I. G. (2015). Recovery kinetics of knee flexor and extensor strength after a football match. *PLoS ONE*, *10*(7).

Ekblom. (1986). Applied physiology of soccer. *Journal of Sports Medicine*, *3*, 50–60.

Ekblom, B., & Goldbarg, A. N. (1971). The influence of physical training and other factors on the subjective rating of perceived exertion. *Acta Physiologica Scandinavica*, *83*(3), 399–406.

Eliakim, E., Doron, O., Meckel, Y., Nemet, D., & Eliakim, A. (2018). Pre-season fitness level and injury rate in professional soccer – A prospective study. *Sports Medicine International Open*, *02*(03), E84–E90.

Fatouros, I. G., Chatzinikolaou, A., Douroudos, I. I., Nikolaidis, M. G., Kyparos, A., Margonis, K., … Jamurtas, A. Z. (2010). Time-course of changes in oxidative stress and antioxidant status responses following a soccer game. *Journal of Strength and Conditioning Research*, *24*(12), 3278–3286.

Fessi, M. S., & Moalla, W. (2018). Postmatch perceived exertion, feeling, and wellness in professional soccer players. *International Journal of Sports Physilogy and Performance*, *13*(5), 631–637.

Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine and Science in Sports and Exercise*, *30*(7), 1164–1168.

Foster, C, Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115.

Foster, C., Hector, L. L., Welsh, R., Schrager, M., Green, M. A., & Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. *European Journal of Applied Physiology and Occupational Physiology*, *70*(4), 367–372.

Gastin, P. B., Meyer, D., Huntsman, E., & Cook, J. (2015). Increase in injury risk with low body mass and aerobic-running fitness in elite Australian football. *International Journal of Sports Physiology and Performance*, *10*(4), 458–463.

Gaudino, P., Iaia, F. M., Strudwick, A. J., Hawkins, R. D., Alberti, G., Atkinson, G., & Gregson, W. (2015). Factors influencing perception of effort (Session rating of perceived exertion) during elite soccer training. *International Journal of Sports Physiology and Performance*, *10*(7), 860–864.

Geurkink, Y., Vandewiele, G., Lievens, M., De Turck, F., Ongenae, F., Matthys, S. P. J., … Bourgois, J. G. (2019). Modeling the prediction of the session rating of perceived exertion in soccer: Unraveling the puzzle of predictive indicators. *International Journal of Sports Physilogy and Performance*, *24*, 1–6.

Gonçalves, B. V, Figueira, B. E., Maçãs, V., & Sampaio, J. (2014). Effect of player position on movement behaviour, physical and physiological performances during an 11-a-side football game. *Journal of Sports Sciences*, *32*(2), 191–199.

Gregson, W., Drust, B., Atkinson, G., & Salvo, V. D. (2010). Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine*, *31*(4), 237–242.

Haddad, M., Stylianides, G., Djaoui, L., Dellal, A., & Chamari, K. (2017). Session-RPE method for training load monitoring: Validity, ecological usefulness, and influencing factors. *Frontiers in Neuroscience*, *11*, 612.

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

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

Jaspers, A., Kuyvenhoven, J. P., Staes, F., Frencken, W. G. P., Helsen, W. F., & Brink,

M. S. (2018). Examination of the external and internal load indicators' association with overuse injuries in professional soccer players. *Journal of Science and Medicine in Sport*, *21*(6), 579–585.

Kempton, T., Sullivan, C., Bilsborough, J. C., Cordy, J., & Coutts, A. J. (2015). Match-to-match variation in physical activity and technical skill measures in professional australian football. *Journal of Science and Medicine in Sport*, *18*(1), 109–113.

Kuipers, H., Verstappen, H., Keizer, P., & Van Kranenburg, G. (1985). Variability of aerobic performance in the laboratory and its physiologic correlates. *International Journal of Sports Medicine*, *6*(4), 197–201.

Kunrath, C. A., Cardoso, F., Nakamura, F. Y., & Teoldo, I. (2018). Mental fatigue as a conditioner of the tactical and physical response in soccer players: A pilot study. *Human Movement*, *19*(3), 16–22.

Léger, L., & Boucher, R. (1980). An indirect continuous running multistage field test: the Université de Montréal track test. *Canadian Journal of Applied Sport Sciences*, *5*(2), 77–84.

Los Arcos, A. (2014). *Control y evaluación de la carga de entrenamiento para la preparación física de jóvenes futbolistas profesionales* (Tesis).

Los Arcos, A., Yanci, J., Mendiguchia, J., & Gorostiaga, E. (2014). Rating of muscular and respiratory perceived exertion in professional soccer players. *Journal of Strength and Conditioning Research*, *28*(11), 3280–3288.

Los Arcos, A, Mendez-Villanueva, A., & Martínez-Santos, R. (2017). In-season training periodization of professional soccer players. *Biology of Sport*, *34*(2), 149–155.

Los Arcos, A., Martínez-Santos, R., Yanci, J., Mendiguchia, J., & Mendez-Villanueva, A. (2015). Negative associations between perceived training load, volume and changes in physical fitness in professional soccer players. *Journal of Sports Science & Medicine*.

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., & Zulueta, J. J. (2015). Effects of small-sided games vs. interval training in aerobic fitness and physical enjoyment in young elite soccer players. *PLoS ONE*, *10*(9).

Los Arcos, A., Yanci, J., Mendiguchia, J., Salinero, J. J., Brughelli, M., & Castagna, C. (2014). Short-term training effects of vertically and horizontally oriented exercises on neuromuscular performance in professional soccer players. *International Journal of Sports Physilogy and Performance*, *9*(3), 480–488.

Macbeth, G., Razumiejczyk, E., & Ledesma, R. (2011). Cliff's Delta Calculator : A non-parametric effect size program for two groups of observations. *Universitas Psychologica*, *10*(2), 545–555.

Malone, S., Owen, A., Mendes, B., Hughes, B., Collins, K., & Gabbett, T. J. (2018). High-speed running and sprinting as an injury risk factor in soccer: Can well-developed physical qualities reduce the risk? *Journal of Science and Medicine in Sport*, *21*(3), 257–262.

Manzi, V., Bovenzi, A., Impellizzeri, F., Carminati, I., & Castagna, C. (2013). Individual training-load and aerobic-fitness variables in premiership soccer players during the precompetitive season. *Journal of Strength and Conditioning Research*, *27*(3), 631–636.

Manzi, V., Iellamo, F., Impellizzeri, F., D'Ottavio, S., & Castagna, C. (2009). Relation between individualized training impulses and performance in distance runners. *Medicine and Science in Sports and Exercise*, *41*(11), 2090–2096.

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.

Mclaren, S., Graham, M., Spears, I., & Weston, M. (2016). The sensitivity of differential ratings of perceived exertion as measures of internal load. *International Journal of Sports Physilogy and Performance*, *11*(3), 404–406.

Mclaren, S., Macpherson, T. W., Coutts, A. J., & Hurst, C. (2018). The relationships between internal and external measures of training load and intensity in team sports : A meta-analysis. *Sports Medicine*, *48*(3), 641–658.

McMorrow, B. J., Ditroilo, M., & Egan, B. (2019). Effect of heavy resisted sled sprint training during the competitive season on sprint and change-of-direction performance in professional soccer players. *International Journal of Sports Physilogy and Performance*, *31*, 1–25.

Mendez-Villanueva, A., Buchheit, M., Simpson, B., & Bourdon, P. C. (2013). Match play intensity distribution in youth soccer. *International Journal of Sports Medicine*, *34*(2), 101–110.

Mendiguchia, J., Edouard, P., Samozino, P., Brughelli, M., Cross, M. R., Ross, A., … Morin, J. B. (2016). Field monitoring of sprinting power-force- velocity profile before, during and after hamstring injury: two case reports. *Journal of Sports*

*Science*, *34*(6), 535–541.

Mendiguchia, J., Martinez-Ruiz, E., Morin, J. B., Samozino, P., Edouard, P., Alcaraz, P. E., … Mendez-Villanueva, A. (2015). Effects of hamstring-emphasized neuromuscular training on strength and sprinting mechanics in football players. *Scandinavian Journal of Medicine and Science in Sports*, *25*(6), 621–629.

Mendiguchia, J., Samozino, P., Martinez-Ruiz, E., Brughelli, M., Schmikli, S., Morin, J. B., & Mendez-Villanueva, A. (2014). Progression of mechanical properties during on-field sprint running after returning to sports from a hamstring muscle injury in soccer players. *International Journal of Sports Medicine*, *35*(8), 690–695.

Mohr, M., Draganidis, D., Chatzinikolaou, A., Barbero-Álvarez, J. C., Castagna, C., Douroudos, I., … Fatouros, I. G. (2016). Muscle damage, inflammatory, immune and performance responses to three football games in 1 week in competitive male players. *European Journal of Applied Physiology*, *116*(1), 179–193.

Morcillo, J. A., Jimenez-Reyes, P., Cuadrado-Penafiel, V., Lozano, E., Ortega-Becerra, M., & Parraga, J. (2015). Relationships between repeated sprint ability, mechanical parameters, and blood metabolites in professional soccer players. *Journal of Strength and Conditioning Research, 29*(6), 1673-1682.

Morin, J.B., Edouard, P., & Samozino, P. (2011). Technical ability of force application as a determinant factor of sprint performance. *Medicine and Science in Sports and Exercise*, *43*(9), 1680–1688.

Morin, J. B., & Sève, P. (2011). Sprint running performance: Comparison between treadmill and field conditions. *European Journal of Applied Physiology*, *111*(8), 1695–1703.

Mujika, I. (2017). Quantification of training and competition loads in endurance sports: Methods and applications. *International Journal of Sports Physilogy and Performance*, *12*(Suppl. 2), S29–S217.

Nedelec, M., McCall, A., Carling, C., Legall, F., Berthoin, S., & Dupont, G. (2014). The influence of soccer playing actions on the recovery kinetics after a soccer match. *Journal of Strength and Conditioning Research*, *28*(6), 1517–1523.

Negra, Y., Chaabene, H., Hammami, M., Hachana, Y., & Granacher, U. (2016). Effects of high-velocity resistance training on athletic performance in prepuberal male soccer athletes. *Journal of Strength and Conditioning Research*, *30*(12), 3290–3297.

Niiniluoto, I. (1993). The aim and structure of applied research. *Erkenntnis*, *38*(1), 1–

21.

Nimmo, M. A., & Ekblom, B. (2007). Fatigue and illness in athletes. *Journal of Sports Sciences*, *25*(SUPPL. 1), 93–102.

Odetoyinbo, K., Wooster, B., & Lane, A. (Eds. ). (2007). *The effect of a succession of matches on the activity profiles of professional soccer players*.

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*, 146–156.

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*, 374–381.

Padrón-Cabo, A., Rey, E., Vidal, B., & García-Nuñez, J. (2019). Work-rate analysis of substitute players in professional soccer: Analysis of seasonal variations. *Journal of Human Kinetics*, *65*(1), 165–174.

Parlebas, P. (2001). Juego, deporte y sociedad. Léxico de praxiología motriz. *Paidotribo*.

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari Bravo, D., Sassi, R., & Impellizzeri, F. M. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, *28*(3), 228–235.

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2007). Variation in top level soccer match performance. *International Journal of Sports Medicine*, *28*(12), 1018–1024.

Raya-González, J., Nakamura, F. Y., Castillo, D., Yanci, J., & Fanchini, M. (2019). Determining the relationship between internal load markers and non-contact injuries in young elite soccer players. *International Journal of Sports Physiology and Performance*, *18*, 1–5.

Rebelo, A., Brito, J., Seabra, A., Oliveira, J., & Krustrup, P. (2014). Physical match performance of youth football players in relation to physical capacity. *European Journal of Sport Science*, *14*, 148–156.

Reilly, B., Akubat, I., Lyons, M., & Collins, D. K. (2015). Match-play demands of elite youth Gaelic football using global positioning system tracking. *Journal of Strength* *and Conditioning Research*, *29*(4), 989–996.

Ritchie, D., Hopkins, W. G., Buchheit, M., Cordy, J., & Bartlett, J. D. (2016). Quantification of training and competition load across a season in an elite Australian football club. *International Journal of Sports Physiology and Performance*, *11*(4), 474–479.

Robertson, R. J., Goss, F. L., Dube, J., Rutkowski, J., Dupain, M., Brennan, C., & Andreacci, J. (2004). Validation of the adult OMNI scale of perceived exertion for cycle ergometer exercise. *Medicine and Science in Sports and Exercise*, *36*(1), 102–108.

Rosch, D., Hodgson, R., Peterson, T. L., Graf-Baumann, T., Junge, A., Chomiak, J., & Dvorak, J. (2000). Assessment and evaluation of football performance. *American Journal of Sports Medicine*, *28*(Suppl 5), S29–S39.

Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Love, T. D., Bracken, R. M., & Kilduff, L. P. (2016). Changes in acceleration and deceleration capacity throughout professional soccer match-play. *Journal of Strength and Conditioning Research*, *30*(10), 2839–2844.

Samozino, P., Edouard, P., Sangnier, S., Brughelli, M., Gimenez, P., & Morin, J. (2014). Force-velocity profile: Imbalance determination and effect on lower limb ballistic performance. *International Journal of Sports Medicine*, *35*(6), 505–510.

Sarmento, H., Clemente, F. M., Araújo, D., Davids, K., McRobert, A., & Figueiredo, A. (2018). What performance analysts need to know about research trends in association football (2012–2016): A systematic review. *Sports Medicine*, *48*(4), 799–836.

Sarmento, H., Marcelino, R., Anguera, M. T., CampaniÇo, J., Matos, N., & LeitÃo, J. C. (2014). Match analysis in football: A systematic review. *Journal of Sports Sciences*, *32*(20), 1831–1843.

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.

Sevil Serrano, J., Práxedes Pizarro, A., García-González, L., Moreno Domínguez, A., & del Villar Álvarez, F. (2017). Evolution of tactical behavior of soccer players across their development. *International Journal of Performance Analysis in Sport*, *17*(6), 885–901.

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. *Sports Medicine,* 48(3), 539-583.

Skiba, P. F. (2006). *Calculation of Power Output and Quantification of Training Stress in Distance Runners: the Development of the GOVSS Algorithm.* Available online at: http://www.physfarm.com/govss.pdf [Online] (Accessed: November 20, 2013).

Sparks, M., Coetzee, B., & Gabbett, T. J. (2017). Internal and external match loads of university-level soccer players: A comparison between methods. *Journal of Strength and Conditioning Research*, *31*(4), 1072–1077.

Stevens, T. G. A., De Ruiter, C. J., Twisk, J. W. R., Geert, 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.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: An update. *Sports Medicine*, *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.

Tang, R., Murtagh, C., Warrington, G., Cable, T., Morgan, O., O'Boyle, A., … Drust, B. (2018). Directional change mediates the physiological response to high-intensity shuttle running in professional soccer players. *Sports*, *6*(2), 39.

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2015). Monitoring fatigue during the in-season competitive phase in elite soccer players. *International Journal of Sports Physiology and Performance*, *10*(8), 958–964.

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.

Varley, M. C., Di Salvo, V., Modonutti, M., Gregson, W., & Mendez-Villanueva, A. (2017). The influence of successive matches on match-running performance during an under-23 international soccer tournament: The necessity of individual analysis. *Journal of Sports Sciences*, *36*(1), 1–7.

Weston, M., Drust, B., Atkinson, G., & Gregson, W. (2011). Variability of soccer referees' match performances. *International Journal of Sports Medicine*, *32*(3), 190–194.

Weston, M. (2013). Difficulties in determining the dose-response nature of competitive soccer matches. *Journal of Athletic Enhancement*, *2*(1).

Whitehead, S., Till, K., Weaving, D., & Jones, B. (2018). The use of microtechnology to quantify the peak match demands of the football codes: A systematic review. *Sports Medicine*, *48*(11), 2549–2575.

Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *Journal of Sports Science*, *30*(15), 1573–1580.

# Chapter 2

## Objectives of the doctoral thesis

# CHAPTER 2. OBJECTIVES OF THE DOCTORAL THESIS

The general objective of the doctoral thesis were to assess the dRPE TL and dRPE ML in different competitive periods throughout training and match sessions, and to evaluate the physical condition in Spanish Second Division professional soccer.

The objectives of the doctoral thesis were the following:

- Objective 1.
    - To compare the weekly respiratory and muscular TL accumulation during the in-season competitive period depending on the length of between-match microcycles and the participation of the players in official matches (three groups: i.e., ≥ 45 min; < 45 min; 0 min) in Spanish professional 2nd Division soccer players.

- Objective 2.
    - To analyse the associations between initial physical fitness and the dRPE TL or dRPE ML accumulated in several periods.

- Objective 3.
    - To assess dRPE ML and its variability according to playing position for Spanish professional soccer players during an entire season.

- Objective 4.
    - To assess the variability of the dRPE ML among professional team soccer players in Spanish league and CupM over a large competitive period (21 matches) by analyzing the development of dRPE ML of players who took part in successive matches in the same week or in three matches per week over several consecutive weeks.

# Chapter 3

## Papers

# Subchapter 3.1. Paper 1

# Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load

Unai Azcárate, Javier Yanci & Asier Los Arcos

*Science and Medicine in Football*, 2018, 2(1), 23-28

# Subchapter 3.1. Paper 1

**Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load**

*Running Title:* Weekly differentiated perceived TL in professional soccer players

Unai Azcárate[1], Javier Yanci [1], Asier Los Arcos[1]

[1]*Physical Education and Sport Department, Faculty of Education and Sport, University of the Basque Country, UPV/EHU, Vitoria-Gasteiz, Spain*

**Abstract**

**Objectives:** To analyze the weekly differentiated perceived training load (dRPE-TL) accumulated during the in-season competitive period by professional soccer players depending on: (1) their participation during the previous official match (i.e., ≥45 min; <45 min; 0 min) and (2) the length of the between match microcycle (8, 7, and 6 days).

**Methods:** Twenty-one Spanish Second Division professional soccer players (age = 26.7 ± 3.1 years; body height = 182.1 ± 4.5 cm; body mass = 76.6 ± 5.6 kg) participated in this study. Weekly dRPE-TL data were collected over a 16-week in-season period during the 2015±2016 season from August to December. After each session, players reported their rating of respiratory (sRPEres) and muscular (sRPEmus) perceived exertions (training load [TL] = sRPE·volume).

**Results:** After the application of the mixed linear model, significant differences ($p < 0.01$) were only found in the differentiated perceived TL measured each week for the groups specified regarding match participation time.

**Conclusions:** Previous match participation had a substantial effect on players' accumulated weekly TLs, with greater match participation associated with higher weekly loads regardless of compensatory training strategies. However, the length of the between-match microcycle during 1-match weeks had no effecton players' accumulated weekly workloads.

***Keywords:*** football; periodisation; perceived exertion; differentiated sRPE

**Introduction**

Despite the fact that the major part of the soccer training session is designed to improve players' tactical competence and prepare for the forthcoming fixtures (Gamble, 2006; Hedrick, 2002; Wathen, Baechle, & Earle, 2000), the biological dimension (i.e., physiological response and physical fitness performance) of the players should also be taken into account in the training periodisation. Accumulated TL brings about, at least partially, changes in physical fitness (Jaspers et al., 2017) and this should be maintained or improved to efficiently meet match running demands over the course of the whole season. Moreover, training sessions should be designed taking into account the need to have sufficient after-game recovery time for elite soccer players (Ascensão et al., 2008; Ispirlidis et al., 2008; Rampinini et al., 2011). Additionally, TL changes from week to week should be controlled in order to minimise the likelihood of injury (Brink et al., 2010; Rogalski, Dawson, Heasman, & Gabbett, 2013). For these reasons, the quantification of workload is required in soccer training.

Among the internal indicators of effort intensity (Buchheit, 2014), the *overall* session rating of PE ($sRPE_o$) is a versatile, easy to use and low-cost option (Borg, 1982) which has been previously validated in soccer players (Alexiou & Coutts, 2008; Casamichana, Castellano, Calleja-Gonzalez, San Román, & Castagna, 2013; Impellizzeri et al., 2004; Scott, Lockie, Knight, Clark, & De Jonge, 2013). Since Foster et al. (2001) proposed the $sRPE_o$ to assess the "hardness" of the entire training session and to evaluate internal TL in endurance and team sport athletes (Foster et al., 2001; Foster, Daines, Hector, Snyder, & Welsh, 1996; Foster et al., 1995), many studies have used this method in order to quantify TL in soccer training (Fessi et al., 2016; Scott et al., 2013; Thorpe et al., 2016). However, this gestalt score could represent an oversimplification of the psychophysiological construct, which in turn could be insufficient for capturing the whole range of exercise-induced perceptual sensations (Hutchinson & Tenenbaum, 2006). For these reasons, several studies have proposed the deconstruction of the $sRPE_o$, the differential ratings of PE (dRPE) (i.e., respiratory and muscular PEs), in order to provide additional information from that obtained by a single measure (Gil-Rey, Lezaun, & Los Arcos, 2015; Los Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014; Los Arcos, Martínez-Santos, Yanci, Mendiguchia, & Mendez-Villanueva, 2015; McLaren, Weston, Smith, Cramb, & Portas, 2015; Weston, Siegler, Bahnert, McBrien, & Lovell, 2015). These measures have been proposed as valid as very large individual correlations have been obtained between dRPE-TL and heart-rate-derived TL in soccer (Los Arcos et al., 2014), they also provide a more detailed quantification of exercise intensity and internal load during training modes commonplace to team sports (McLaren, Smith, Spears, & Weston, 2016), and, furthermore, some substantial associations have been found between respiratory and muscular perceived TL and changes in physical fitness performance in professional soccer players (Jaspers et al., 2016; Los Arcos et al., 2015, 2014).

Soccer team periodisation strategies are relatively unknown (Anderson et al., 2016; Loturco et al., 2016; Malone et al., 2015). It is normal practice in soccer to design a first phase (i.e., pre-season) of three to five weeks as a means of preparation for the rest of the season (Coutts, Chamari, Impellizzeri, & Rampinini, 2008). Then, a much longer second phase consisting of the competitive season is carried out (i.e., in-season) (Coutts, Chamari, Rampinini, & Impellizzeri, 2008). However, little research has systematically attempted to describe the distribution of weekly TL across the different periods of the season in professional soccer players (Anderson et al., 2016; Malone et al., 2015). Malone et al. (2015) found higher weekly TL (i.e. total distance covered and perceived TL) at the beginning (weeks 7–12) compared to at the end of the season (weeks 37–42), but weekly TLs remained constant throughout the other mesocycles of the season phase in professional soccer players. These results suggested that the monotony of TL is related to the in-season period. In addition, the results indicated that the daily TL was steady across most training days of the week in the in-season period, except for the day before a match, when the load was significantly reduced. However, these authors did not distinguish the group players according to their in-match participation time, nor did they differentiate between the weeks with respect to the length of the between-match microcycle.

In another study, Anderson et al. (2016) distinguished ST (starting ≥ 60% of games), fringe (starting 30–60% of games) and N-S (starting < 30% of games) players and found significant differences in external TL (i.e. running, high-speed running, sprinting, duration of total activity and total distance) between these groups during the training sessions in five different in-season periods. Therefore, it would be appealing to add ML, differentiating the players of the same team who were classified as ST, fringe and N-S, depending on their participation time in each official match. Nevertheless, no study has analysed weekly differential sRPE distribution along the in-season period in professional soccer players according to their participation during the official match prior to the training week, and the length of the between-match microcycle.

Therefore, the aim of this study was to compare the weekly respiratory and muscular TL accumulation during the in-season competitive period depending on the length of between-match microcycles and the participation of the players in official matches (three groups: i.e., ≥ 45 min; < 45 min; 0 min) in Spanish professional 2nd Division soccer players.

## Methods

### *Participants*

Twenty-one outfield professional soccer players (age = 26.7 ± 3.1 years; body height = 182.1 ± 4.5 cm; body mass = 76.6 ± 5.6 kg) competing in the Spanish Second Division League participated in this study. The participating players consisted of three central defenders, five wide defenders, four central midfielders, five wide midfielders and two strikers. They trained five to six times per week and participated in one or two official matches. All participants were informed about the research procedures, requirements, benefits and risks prior to giving their written consent. The study was conducted according to the Declaration of Helsinki and was approved by the local Ethics Committee.

### *Procedures*

Weekly perceived TL data (i.e., sum of the match perceived load and the perceived TL from the weekly sessions prior to the next match) were collected over a 16-week in-season period during the 2015–2016 season from the last week of August (i.e., seventh week of training, first week of official competition) to the second week of December (i.e., training week 22) in the first half of the in-season. Training weeks (Table 1) were classified according to the previous match day and the next match day (i.e., Saturday or Sunday), distinguishing four types of weeks: a) Saturday– Sunday (Sat–Sun), eight days; b) Sunday–Sunday (Sun–Sun), seven days; c) Saturday–Saturday (Sat–Sat), seven days; d) Sunday–Saturday (Sun–Sat), six days. Weeks where a Spanish

King's Cup match was held (i.e., two matches per week) were not included in the analysis.

Therefore, TL of the remaining weeks (Sat–Sun: three weeks, 21 players, 61 total occurrences; Sun–Sun: three weeks, 21 players, 62 total occurrences; Sat–Sat: four weeks, 21 players, 81 total occurrences; Sun–Sat: three weeks, 21 players, 60 total occurrences) was retained for further analysis. In addition, only the players that were available to train for a whole week with the team and also compete during the weekend were considered. Then, available players were distributed in three groups: a) players that completed all training sessions and participated during at least 45 min in the official match (≥ 45 min), b) players who completed all training sessions and participated during less than 45 minutes in the official match (< 45 min), and c) players who completed all training sessions but did not participate in the official match (0 min). Typically, players who did not participate or those that played less than 45 minutes in the official match carried out a compensatory soccer training session straight after the official game.

**Table 1.** Description of four different types of weeks according to the days of training and rest per week

| | ***Monday*** | ***Tuesday*** | | ***Wednesday*** | | ***Thursday*** | ***Friday*** | ***Saturday*** | ***Sunday*** |
|---|---|---|---|---|---|---|---|---|---|
| | AM | AM | PM | AM | PM | AM | PM | AM/PM | PM |
| **Sat-Sun (3)**<br>**Sun-Sun (3)** | ST: Low intensity continuous running, stretching. N-S: Continuous running, SSGs | Rest | Rest | Endurance, SSGs | PLY, speed output | CT, RSA, arrivals goals | Injury prevention, strategy | R. Speed, arrivals goals | Match |
| **Sat-Sat (4)**<br>**Sun-Sat (3)** | ST: Low intensity continuous running, stretching. N-S: Continuous running, SSGs | Endurance, SSGs | PLY, speed output | CT, RSA, arrivals goals | | Injury prevention, strategy | R. Speed, arrivals goals | Match | Rest |
| **Volume (min)** | S: 35-45<br>N-S: 53-56 | 45-53 | 46-51 | 53-65 | | 43-65 | 44-68 | 40-50 | |

Sat–Sun = week from Saturday to Sunday; Sun–Sun = week from Sunday to Sunday; Sat–Sat = week from Saturday to Saturday; Sun–Sat = week from Sunday to Saturday; ST = Starters; N-S = Non-Starters; SSGs = small-sided soccer games; PLY = plyometric; CT = Collective technique; RSA = repeated sprint ability; R. Speed = Reaction Speed.

***Differentiated Perceived TL***

In order to quantify TL, the sRPE-TL method (Foster et al., 2001) was used. Ten minutes after each training session and match (Los Arcos, Martínez-Santos, Yanci, & Mendiguchia, 2015; Ngo et al., 2012) and using Foster's 0-10 scale (Foster et al., 2001) players were asked to assess their PE so that their sRPE-TL could be obtained. This question was asked by the same person every time (i.e. fitness coach) with regard to players' respiratory and leg musculature effort so that a separate measurement for respiratory PE (sRPEres) and muscular PE (sRPEmus) could be obtained (Los Arcos, Mendez-Villanueva, Yanci, & Martinez-Santos, 2016; Los Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014; Los Arcos, Martínez-Santos, Yanci, Mendiguchia, & Mendez-Villanueva, 2015; Weston, Siegler, Bahnert, McBrien, & Lovell, 2015).

Players responded to two simple questions on a single evaluation sheet, and the questions were always asked in this order: How hard was your session on your chest? How hard was your session on your legs? Players were allowed to mark a plus sign (interpreted as 0.5 point) alongside the integer value (Los Arcos, Yanci, Mendiguchia, & Gorostiaga, 2014; Los Arcos et al., 2016; Los Arcos et al., 2015). Each player completed the 0–10 scale randomly without the presence of other players and they could not see the values of other participants. All players were familiarised with this method during the pre-season period (seven weeks; from July 9th to August 23rd). Both respiratory and muscular perceived TLs (sRPEres-TL and sRPEmus-TL) were calculated, multiplying the sRPE value by the duration of the training session or match (Los Arcos et al., 2014; Los Arcos et al., 2015). Training duration was recorded individually from the beginning (including warm-up and recovery periods) to the end of the session (excluding cool-down or stretching exercises) (Los Arcos et al., 2014; Los Arcos et al., 2016; Los Arcos et al., 2015). The match duration was recorded, excluding warm-up and half-time rest periods (Los Arcos et al., 2014; Yanci, Martínez-Santos, & Los Arcos, 2014).

***Statistical Analysis***

Descriptive results are presented as means ± standard deviations (SD). Mixed linear modelling was applied in order to analyse the mixture of both fixed (i.e., types of week and match participation time groups) and random effects (i.e., individual players) in the weekly differentiated perceived TL. When one or more fixed effects were statistically significant, Tukey post-hoc pairwise comparisons were performed to examine contrasts between pairs of categories of the significant factor(s). Data were analysed using mixed linear modelling with the Statistical Package for Social Sciences (version 23.0 for Windows, SPSS Inc, Chicago, IL, USA). Significance was set at $p < 0.05$.

**Results**

The accumulated differentiated perceived TL by the Spanish professional soccer players ranged from 1102 ± 217 AUs to 1314 ± 242 AUs, from 965 ± 138 AUs to 1065 ± 258 AUs and from 800 ± 174 AUs to 864 ± 238 AUs for the players that participated for at least 45 min, for less than 45 min and did not participate in the match, respectively.

There were significant differences ($p < 0.05$) in total volume between all playing time groups (i.e., ≥ 45 min; < 45 min; 0 min) but only between type 1 (Sun–Sun) and 4 (Sat–Sun) weeks ($p < 0.01$). The interaction between type of week and playing time groups did not show significant differences ($P = 0.51$).

There were significant differences ($p < 0.01$; $F(2) = 67.992$) in weekly differentiated perceived TL (i.e., respiratory and muscular TL) among the groups specified regarding match participation time (i.e., players that completed all training sessions and participated for at least 45 min in the official match (≥ 45 min), players who completed all training sessions and participated for less than 45 minutes in the official match (< 45 min), and players who completed all training sessions but did not participate in the official match (0 min)); sRPEres-TL: ≥ 45 min vs. < 45 min (mean difference = 174 AUs; $p < 0.01$), ≥ 45 min vs. 0 min (mean difference = 323 AUs; $p < 0.01$) and < 45 min vs. 0 min (mean difference = 149 AUs; $p < 0.01$), sRPEmus-TL: ≥ 45 min vs. < 45 min (mean difference = 218 AUs; $p < 0.01$), ≥ 45 min vs. 0 min (mean difference = 427 AUs; $p < 0.01$) and < 45 min vs. 0 min (mean difference = 209 AUs; $p < 0.01$) (Figures 1 and 2).

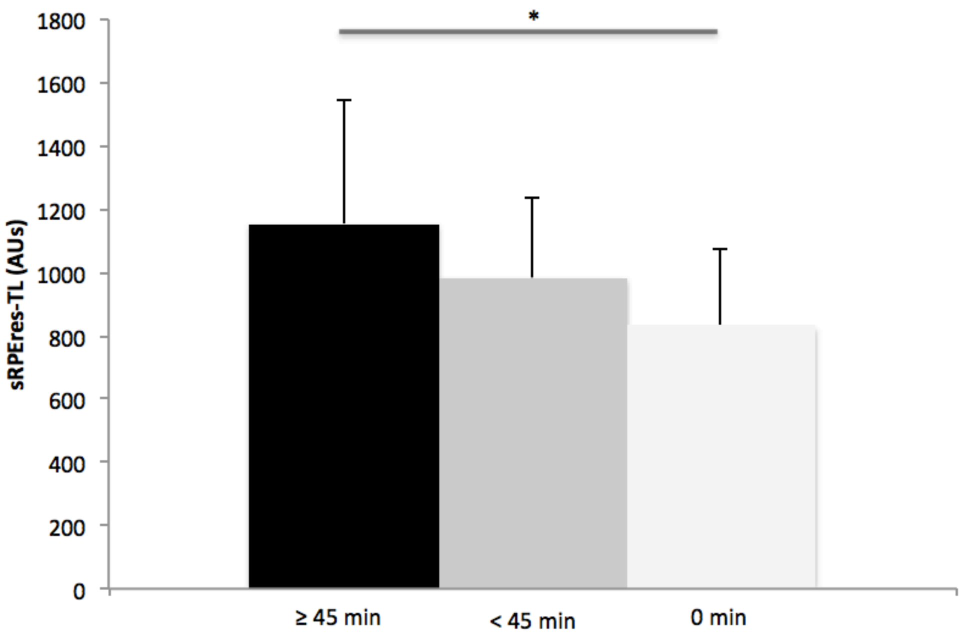


**Figure 1.** Weekly accumulated sRPEres-TL depending on the participation in official match (≥ 45 min, players that participated at least 45 min; < 45min, players that participated less than 45 min; and 0 min, players that did not participate in the match) regardless the week type.
sRPEres-TL = respiratory session-rating of perceived exertion training load; *$p$ = 0.00 = Significant differences between all groups.

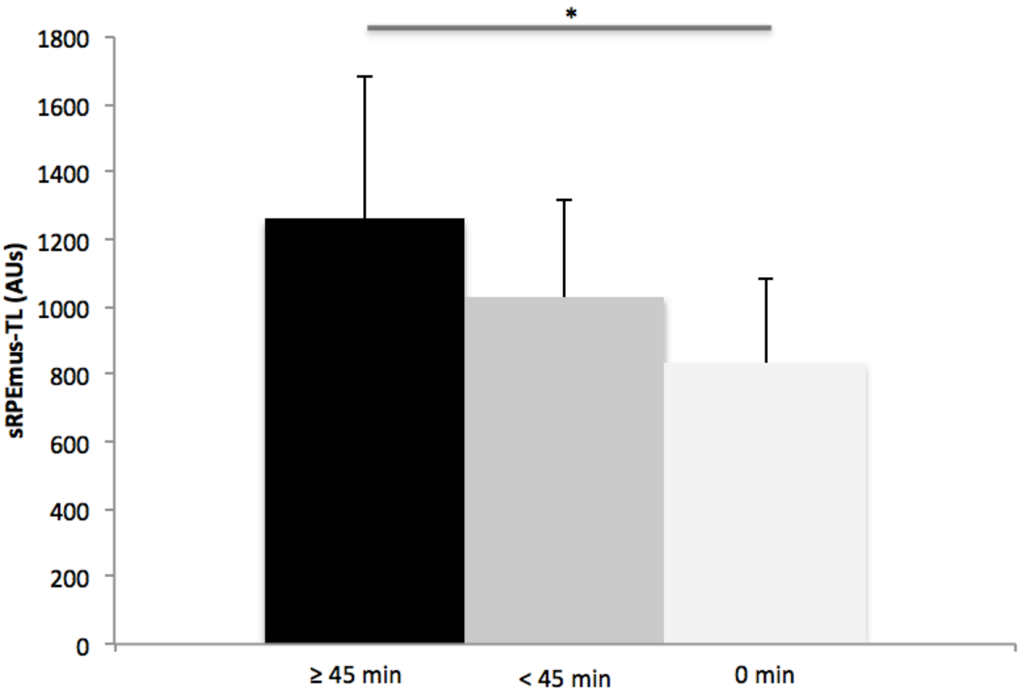


**Figure 2.** Weekly accumulated sRPEmus-TL depending on the participation in official match (≥ 45 min, players that participated at least 45 min; < 45min, players that participated less than 45 min; and 0 min, players that did not participate in the match) regardless the week type.
sRPEmus-TL = muscular session-rating of perceived exertion training load; *$p$ = 0.00 = Significant differences between all groups.

There were no significant differences ($p$ = 0.77; F(3) = 0.371) in weekly differentiated perceived TL (i.e., respiratory and muscular TL) between the types of week (Sat–Sun, Sun–Sun, Sat–Sat, and Sun–Sat). There were no significant differences ($p$ = 0.588; F(6) = 0.816) in weekly differentiated perceived TL (i.e., respiratory and muscular TL) in the interaction between the types of week and match participation time groups (Figures 3 and 4).

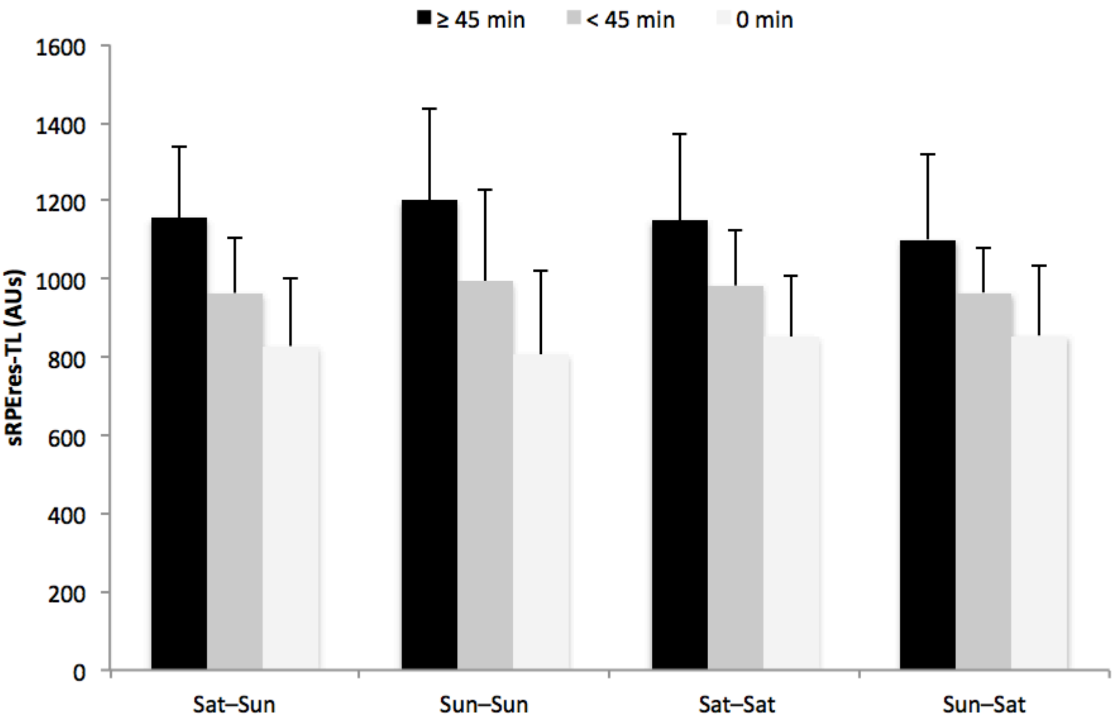


**Figure 3.** Weekly accumulated sRPEres-TL on several training week types, depending on the participation in official match (≥ 45 min, players that participated at least 45 min; < 45min, players that participated less than 45 min; and 0 min, players that did not participate in the match).
TL = training load; sRPEres-TL = respiratory session-rating of perceived exertion training load; Sat–Sun = week from Saturday to Sunday; Sun–Sun = week from Sunday to Sunday; Sat–Sat = week from Saturday to Saturday; Sun–Sat = week from Sunday to Saturday; AUs = arbitrary units; Sat-Sun (8 days per week): ≥ 45 min = 33 occurrences, < 45 min = 8 occurrences, 0 min = 20 occurrences; Sun-Sun (7 days per week): ≥ 45 min = 34 occurrences, < 45 min = 8 occurrences, 0 min = 20 occurrences; Sat-Sat (7 days per week): ≥ 45 min = 46 occurrences, < 45 min = 11 occurrences, 0 min = 24 occurrences; Sun-Sat (6 days per week): ≥ 45 min = 35 occurrences, < 45 min = 7 occurrences, 0 min = 18 occurrences.

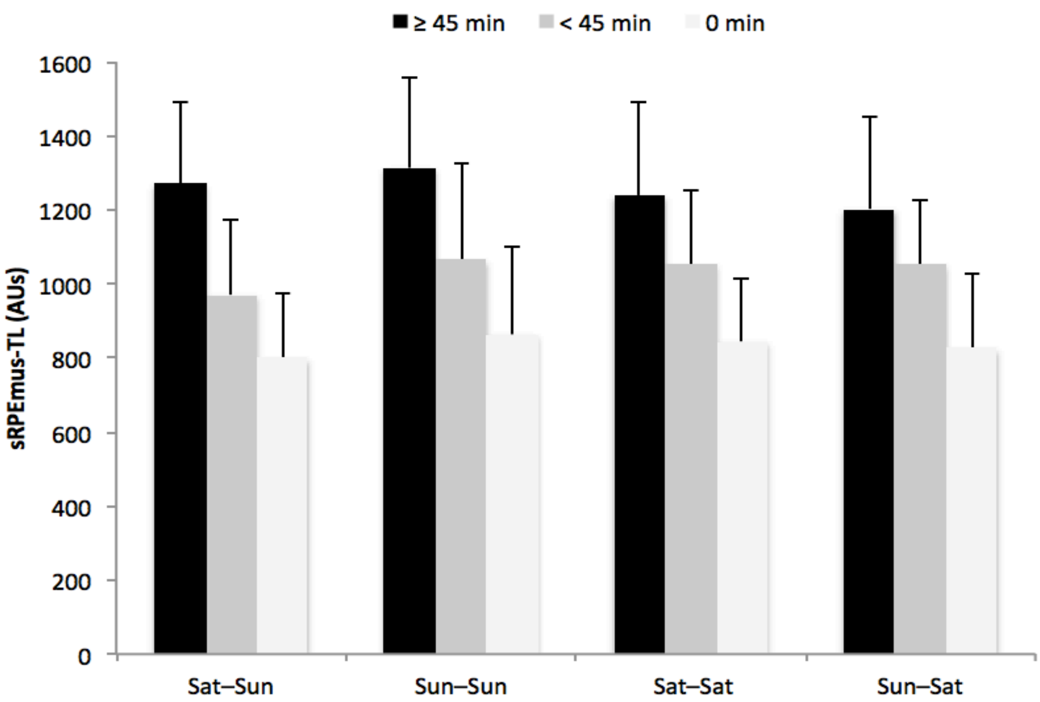


**Figure 4.** Weekly accumulated sRPEmus-TL on several training week types, depending on the participation in official match (≥ 45 min, players that participated at least 45 min; < 45min, players that participated less than 45 min; and 0 min, players that did not participate in the match).
TL = training load; sRPEmus-TL = muscular session-rating of perceived exertion training load; Sat–Sun = week from Saturday to Sunday; Sun–Sun = week from Sunday to Sunday; Sat–Sat = week from Saturday to Saturday; Sun–Sat = week from Sunday to Saturday; AUs = arbitrary units; Sat-Sun (8 days per week): ≥ 45 min = 33 occurrences, < 45 min = 8 occurrences, 0 min = 20 occurrences; Sun-Sun (days per week): ≥ 45 min = 34 occurrences, < 45 min = 8 occurrences, 0 min = 20 occurrences; Sat-Sat (7 days per week): ≥ 45 min = 46 occurrences, < 45 min = 11 occurrences, 0 min = 24 occurrences; Sun-Sat (6 days per week): ≥ 45 min = 35 occurrences, < 45 min = 7 occurrences, 0 min = 18 occurrences.

## Discussion

The aims of this study were to analyse the weekly differentiated perceived TL (sRPE-TL) accumulated by Spanish Second Division soccer players depending on their participation (i.e., ≥ 45 min; < 45 min; 0 min) during the official match prior to the training week, and the length of the between-match microcycle (Sat–Sun, eight days; Sun–Sun, seven days; Sat–Sat, seven days; Sun–Sat, six days). The main findings of the present study were: a) the amount of time players participate in the official match prior to the training week determines their weekly TL accumulation and results in the production of differences among players in the same team, enabling the differentiation of three groups of players, and b) the length of the training week after the match does not affect players' accumulated perceived TL in any of the three groups (i.e., ≥ 45 min; < 45 min; 0 min). These results suggest that the applied training strategies during the week do not compensate for the impact of the low participation in prior matches; in addition, the variability of the TL across the in-season period is not significant although the number of days included in the training week changed during the season.

The average weekly sRPE-TL accumulated by professional Spanish soccer players during the in-season period did not exceed 1350 AUs, even in the case of players that participated for at least 45 min during the match and also completed all trainings sessions for the four types of weeks. This respiratory and muscular TL was considerably lower than the one reported in the case of Spanish semi-professional and professional soccer players (Los Arcos et al., 2015, 2014; Yanci, 2016). In these studies, in-season weekly differentiated TL was approximately 1500–1600 AUs (Arcos et al., 2014; Los Arcos et al., 2015) and 1700–1900 AUs (Yanci, Los Arcos, Camara, Castillo, Garcia, & Castagna, 2016) including players that did and those who did not take part in official matches (Los Arcos et al., 2015, 2014; Yanci et al., 2016). These substantial differences suggest that the training strategies differ considerably among Spanish soccer teams and players at higher competitive levels who did not accumulate a greater perceived TL. In order to assess the impact of these substantial differences on physical fitness (Los Arcos et al., 2014; Gil-Rey et al., 2015; Los Arcos et al., 2015), injury, and illness, as Jaspers et al. (2016) suggested, future research should implement continuous monitoring of TL, combined with the individual characteristics of the players that could limit the external validity of the examined TL indicators and corresponding outcomes in soccer training.

In comparison to previous studies (Algrøy et al., 2011; Fessi et al., 2016; Jeong, Reilly, Morton, Bae, & Drust, 2011; Malone et al., 2015), to quantify weekly TL, we differentiated three groups, depending on the playing time in the official match (≥ 45 min, < 45 min and 0 min) instead of including all of the players together in one single group. Match participation time produced differences in perceived weekly TL, regardless of the type of week, among players in the same team. Therefore, players' weekly accumulated TL prior to the next match (i.e., previous match and training sessions) varied considerably among members of the same soccer team. This suggests that the designed weekly training strategies do not compensate for the TL accumulated during the match, not only for the players who did not participate in the match but also with regard to players who participated for less than 45 min. Despite performing substitute training the first training session of the week to compensate for the TL accumulated after participating in the game, this was not enough to reach the weekly accumulated TL of players that played ≥ 45 min during the match. A previous study (Kraemer et al., 2004) shows changes in exercise performance between two groups (i.e., ST and N-S) and that ST were found to have significant reductions in both sprint speed (+4.3%) and vertical jump height (-13.8%) throughout the season compared to preseason values. Data indicate that players experienced reductions in performance throughout the season, with performance decrements exacerbated in ST compared to N-S. This suggests that coaches should consider whether performing substitute training is needed and achieves the long-term objectives. Therefore, all this data highlight the need for further research to suggest "optimal" weekly sRPE-TL references in soccer training.

Regardless of the length of the week (Sat–Sun, eight days; Sun–Sun, seven days; Sat–Sat, seven days; Sun–Sat, six days), the weekly perceived TL was constant throughout the in-season period in professional soccer players. This training monotony was also found in other studies in Tunisian (Fessi et al., 2016) and English soccer players (Anderson et al., 2016; Malone et al., 2015). However, to our knowledge, ours is the first research that has analysed four different types of weeks, according to the length of the between-match training week after the match and depending on the total playing time in official matches for each player, with the weekly TL similar across the season, independently of the length of the between-match training week and for the three players' groups. In order to maintain a regular performance, specific for this sport and level, that would last for an eight-month period (including weekly matches), soccer technical staff follow a similar training strategy with all the players throughout the season. The TL does not differ considerably across the different week lengths, and this is distributed in the available training days, varying only relative to the weekly TL-recovery. These results and the reduction of TL one day before the next match (Gaudino et al., 2013; Los Arcos et al., 2014; Malone et al., 2015) suggest that the week is the soccer training periodisation unit in professional soccer training. Since match situational variables affected the weekly perceived TL in junior soccer players (Brito et al., 2016), the impact of these factors could also be assessed in professional soccer players. As Issurin (2010) indicated, the preparation planning in team sports differs drastically from planning routines in individual athletic disciplines. For future research, it would be of great interest to analyse periodisation of TL between matches, according to the days of training per week, considering whether substitute training is needed for the physical fitness performance of player's who complete all training sessions and participate less than 45 min or do not participate in the official match with regard to a similar weekly periodisation. Taking into account that the application of our findings is limited to 1-match weeks, it would be interesting to analyse the load distribution among the soccer teams which played a series of matches throughout the week (i.e., Champions league, UEFA, King's Cup, regular league).

**Conclusions**

Previous match participation had a substantial effect on players' accumulated weekly TLs, with greater match participation associated with higher weekly loads regardless of compensatory training strategies. On the other hand, the length of the between-match microcycle during 1-match weeks had no effect on players' accumulated weekly workloads.

## References

Alexiou, H., & Coutts, A. (2008). A comparison of methods used for quantifying internal training load in women soccer players. *International Journal of Sports Physiology and Performance*, *3*, 320–330.

Algrøy, E. A., Hetlelid, K. J., Seiler, S., & Pedersen, J. I. (2011). Quantifying training intensity distribution in a group of Norwegian professional soccer players. *International Journal of Sports Physiology and Performance*, *6*(1), 70–81.

Anderson, L., Orme, P., Di Michele, R., Close, G. L., Milsom, J., Morgans, R., … Morton, P. (2016). Quantification of seasonal long physical load in soccer players with different starting status from the English Premier League: Implications for maintaining squad physical fitness. *International Journal of Sports Physilogy and Performance*, *11*(8), 1038–1046.

Arcos, A. L., Yanci, J., Mendiguchia, J., & Gorostiaga, E. M. (2014). Rating of muscular and respiratory perceived exertion in professional soccer players. *Journal of Strength and Conditioning Research*, *28*(11), 3280–3288.

Ascensão, A., Rebelo, A., Oliveira, E., Marques, F., Pereira, L., & Magalhães, J. (2008). Biochemical impact of a soccer match - analysis of oxidative stress and muscle damage markers throughout recovery. *Clinical Biochemistry*, *41*(10–11), 841–851.

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, *14*(5), 377–381.

Brink, M. S., Visscher, C., Arends, S., Zwerver, J., Post, W. J., & Lemmink, K. A. (2010). Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. *British Journal of Sports Medicine*, *44*(11), 809–815.

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.

Buchheit, M. (2014). Monitoring training status with HR measures: Do all roads lead to Rome? *Frontiers in Physiology*, *5*(73).

Casamichana, D, Castellano, J., Calleja-Gonzalez, J., San Román, J., & Castagna, C. (2013). Relationship between indicators of training load in soccer players. *Journal of Strength and Conditioning Research*, *27*(2), 369–374.

Coutts, Aaron J, Chamari, K., Rampinini, E., & Impellizzeri, F. (2008). Monitoring training in football: Measuring and periodising training. In *From Training to*

*Performance in Soccer* (pp. 242–263). Paris, France: De Boeck Universite.

Fessi, M., Zarrouk, N., Di Salvo, V., Filetti, C., Barker, A. R., & Moalla, W. (2016). Effects of tapering on physical match activities in professional soccer players. *Journal of Sports Sciences*, *34*(24), 2189–2194.

Foster, C, Daines, E., Hector, L., Snyder, A. C., & Welsh, R. (1996). Athletic performance in relation to training load. *Wisconsin Medical Journal*, *95*, 370–374.

Foster, C, Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115.

Foster, C., Hector, L. L., Welsh, R., Schrager, M., Green, M. A., & Snyder, A. C. (1995). Effects of specific versus cross-training on running performance. *European Journal of Applied Physiology and Occupational Physiology*, *70*(4), 367–372.

Gamble, P. (2006). Periodization of training for team sports athletes. *Strength and Conditioning Journal*, *28*(5), 56–66.

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.

Gil-Rey, E., Lezaun, A., & Los Arcos, A. (2015). Quantification of the perceived training load and its relationship with changes in physical fitness performance in junior soccer players. *Journal of Sports Sciences*, *33*(20), 2125–2132.

Hedrick, A. (2002). Designing effective resistance training programs: A practical example. *Strength and Conditioning Journal*, *24*(6), 7–15.

Hutchinson, J. C. &, & Tenenbaum, G. (2006). Perceived effort: Can it be considered Gestalt? *Physiology of Sport and Exercise*, *7*(5), 463–476.

Impellizzeri, M., Rampinini, E., Coutts, J., Sassi, A., & Marcora, M. (2004). Use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise*, *36*(6), 1042–1047.

Ispirlidis, I., Fatouros, I. G., Jamurtas, A. Z., Nikolaidis, M. G., Michailidis, I., Douroudos, I., … Taxildaris, K. (2008). Time-course of changes in inflammatory and performance responses following a soccer game. *Clinical Journal of Sport Medicine*, *18*(5), 423–431.

Issurin, V. B. (2010). New horizons for the methodology and phsiology of training periodization. *Sports Medicine*, *40*(3), 189–206.

Jaspers, A., Brink, M. S., Probst, S. G., Frencken, W. G., & Helsen, W. F. (2017). Relationships between training load indicators and training outcomes in professional soccer. *Sports Medicine*, *47*(3), 533–544.

Jeong, T.-S., Reilly, T., Morton, J., Bae, S.-W., & Drust, B. (2011). Quantification of the physiological loading of one week of "pre-season" and one week of "in-season" training in professional soccer players. *Journal of Sports Sciences*, *29*(11), 1161–1166.

Kraemer, W. J., French, D., Paxton, N. J., Hakkinen, K., Volek, J. S., Sebastianelli, W. J., … Vescovi, J. D. (2004). Changes in exercise performance and hormonal concentrations over a big ten soccer season in starters and nonstarters. *Journal of Strength and Conditioning Research*, *18*(1), 121–128.

Los Arcos, A., Martínez-santos, R., Yanci, J., Mendiguchia, J., & Méndez-Villanueva, A. (2015). Negative associations between perceived training load, volume and changes in physical fitness in professional soccer players. *Journal of Sports Science & Medicine*, *14*(2), 394–401.

Los Arcos, A., Mendez-Villanueva, A., Yanci, J., & Martinez-Santos, R. (2016). Respiratory and muscular perceived exertion during official games in professional soccer players. *International Journal of Sports Physiology and Performance*, *11*(3), 301–304.

Loturco, I., Nakamura, F. Y., Kobal, R., Gil, S., Pivetti, B., Pereira, L. A., & Roschel, H. (2016). Traditional periodization versus optimum training load applied to soccer players: Effects on neuromuscular abilities. *International Journal of Sports Medicine*, *37*(13), 1051–1059.

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.

McLaren, S. J., Weston, M., Smith, A., Cramb, R., & Portas, M. D. (2015). Variability of physical performance and player match loads in professional rugby union. *Journal of Science and Medicine in Sport*, *19*(6), 493–497.

McLaren, S., Smith, A., Spears, I., & Weston, M. (2017). A detailed quantification of differential ratings of perceived exertion during team-sport training. *Journal of Science and Medicine in Sport*, *20*(3), 290–295.

Ngo, J. K., Tsui, M. C., Smith, A. W., Carling, C., Chan, G. S., & Wong, D. P. (2012).

The effects of man-marking on work intensity in small-sided soccer games. *Journal of Sports Science and Medicine*, *11*(1), 109–114.

Rampinini, E., Bosio, A., Ferraresi, I., Petruolo, A., Morelli, A., & Sassi, A. (2011). Match-related fatigue in soccer players. *Medicine and Science in Sports and Exercise*, *43*(11), 2161–2170.

Rogalski, B., Dawson, B., Heasman, J., & Gabbett, T. J. (2013). Training and game loads and injury risk in elite Austrailan footballers. *Journal of Science and Medicine in Sport*, *16*(6), 499–503.

Scott, B. R., Lockie, R. G., Knight, T. J., Clark, A. C., & Janse de Jonge, X. A. (2013). A Comparison of methods to quantify the in-Season training load of professional soccer players. *International Journal of Sports Physiology and Performance*, *8*(2), 195–202.

Thorpe, R.T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2016). Tracking morning fatigue status across in-Season training weeks in elite soccer players. *International Journal of Sports Physiology and Performance*, *11*(7), 947–952.

Wathen, D., Baechle, T. R., & Earle, R. W. (2000). Training variation: Periodization. In: Essentials of strength training & conditioning (2nd. ed.). Champaign, IL: Human Kinetics.

Weston, Matthew, Siegler, J., Bahnert, A., McBrien, J., & Lovell, R. (2015). The application of differential ratings of perceived exertion to Australian Football League matches. *Journal of Science and Medicine in Sport*, *18*(6), 704–708.

Yanci, J., Los Arcos, A., Camara, J., Castillo, D., Garcia, A., & Castagna, C. (2016). Effects of horizontal plyometric-training volume on soccer players´ performance. *Research in Sports Medicine*, *24*(4), 308–319.

Yanci, J., Martínez-Santos, R., & Los Arcos, A. (2014). Respiratory and muscular perceived efforts after official games in professional soccer players. *Journal of Strength and Conditioning Research*, *28*(11), 45–53.

# Subchapter 3.2. Paper 2

# Are acceleration and cardiovascular capacities related to perceived load in professional soccer players?

Unai Azcárate, Asier Los Arcos, Pedro Jiménez-Reyes & Javier Yanci

*Research in Sports Medicine,* 2020, 28(1), 27-41

## Subchapter 3.2. Paper 2

**Are acceleration and cardiovascular capacities related to perceived load in professional soccer players?**

*Running Title:* Physical fitness in professional soccer players

Unai Azcárate[1], Asier Los Arcos[1], Pedro Jiménez-Reyes[2], Javier Yanci[1]

[1]*Physical Education and Sport Department, Faculty of Education and Sport, University of the Basque Country, UPV/EHU, Vitoria-Gasteiz, Spain.* [2] *Centre for Sport Studies, King Juan Carlos University, Madrid, Spain*

**Abstract**

This study aims at assessing physical fitness performance and its relationship with the differential ratings of perceived exertion of training load (dRPE TL) and match load (dRPE ML) in a Spanish professional soccer team at the beginning of several in-season periods: 1–4 weeks, 5–8 weeks and 1–8 weeks. Performance and mechanical variables over the acceleration phase, as well as cardiovascular performance variables were evaluated in 20 male professional soccer players of a team competing in the Spanish Second Division League. Moreover, dRPE TL and dRPE ML were quantified. The dRPE TL showed negative and large associations between both maximal aerobic speed (MAS) and maximal oxygen consumption ($VO_{2max}$) (from r = -0.53; ± 0.06 to r = -0.53; ± 0.05 95% CL, *p = 0.035 to 0.036*) and RPEres TL values throughout the 5–8 and 1–8 week periods. Furthermore, dRPE ML positive and large associations were found between players initial MAS or $VO_{2max}$ (from r = 0.50; ± 0.17 to r = 0.56; ± 0.11 95% CL, *p = 0.026 to 0.049*) and RPEmus ML in 1–4 and 1–8 week periods. The current study suggests that a better cardiovascular capacity could be connected with a lower RPEres TL and higher RPEmus ML.

***Keywords**:* speed, endurance, perceived exertion, internal load.

## Introduction

Physical demands in soccer games have been analysed through the quantification of external load [global positioning systems or local positioning systems] (Martín-García, Gómez-Díaz, Bradley, Morera, & Casamichana, 2018; Oliveira et al., 2019) and internal load (heart rate monitoring or rating of PE) (Beato, Jamil, & Devereux, 2018; Geurkink et al., 2019; Jaspers et al., 2018). Despite the fact that soccer is a complex and unpredictable sport, from a physical performance point of view, it is a sports modality with intermittent actions that involve different physical demands [such as sprints, dribbles, acceleration, deceleration or change of directions (CODs)] (McMorrow, Ditroilo, & Egan, 2019; Russell et al., 2016). In addition, many of the relevant actions in soccer are preceded by short accelerations of a very high intensity (HI) (Ade, Fitzpatrick, & Bradley, 2016; Clemente et al., 2019; Tang et al., 2018). Because the very HI is associated with performance in different competition actions (such as dribbles, CODs, penetrative passes, etc.) (Bradley et al., 2010), special attention has recently been paid to the assessment and training of acceleration capacity (Weston et al., 2015) in order to obtain better physical performance. Although a great deal of research has measured the acceleration capacity of professional soccer players through assessment of physical performance (i.e. time spent at distance covered) (Abbott, Brickley, Smeeton, & Mills, 2018; Mendiguchia et al., 2016), it may also be interesting to know the behavior of mechanical variables (Mendiguchia et al., 2016; Morin, Edouard, & Samozino, 2011; Morin and Sève, 2011). Accordingly, several studies have also analysed mechanical variables in soccer players competing at different levels (Mendiguchia et al., 2016, 2014; Morcillo et al., 2015). Nevertheless, further research is required to provide a complete mechanical profile of professional soccer players.

In order to ensure an appropriate execution in professional soccer and in this light of physical performance, acceleration is not the only relevant capacity. Due to the fact that the duration of an official soccer match is approximately 90 min, players typically cover a distance of 10–14 km per match (Anderson et al., 2016), and simultaneously, these are required to develop a large amount of short actions throughout its duration (Morcillo et al., 2015). Therefore, a successful recovery during the intense phases of the match is especially important, inasmuch as cardiovascular capacity plays a significant role (Silva et al., 2018; Thorpe et al., 2016). Likewise, it has been reported that top-level players with better cardiovascular performance are able to cover greater distances at high-intensity in matches (Bradley et al., 2010). Therefore, professional soccer players, in addition to a suitable acceleration capacity should also show an appropriate cardiovascular performance.

Furthermore, several studies have evaluated a key factor in the performance of soccer players: ML and TL (Jaspers, Brink, Probst, Frencken, & Helsen, 2017; Malone et al., 2015). In fact, the accumulated load throughout different weeks has been signaled as a determining factor in the physiological adaptations of players (Malone et al., 2015) and it has also been suggested that it affect fatigue levels and the risk of physical injury (Bowen, Gross, Gimpel, & Li, 2017; Malone et al., 2018). Along these lines, other researchers (Gastin et al., 2015; Jaspers et al., 2017) have analysed whether the initial physical fitness of soccer players could also be associated with TL and ML as well as with the risk of injury. Gastin et al. (2015) showed that low physical fitness was associated with a higher risk of injury in professional Australian soccer players. As a final note in relation to the studies just mentioned, although the associations between initial physical fitness and TL and ML have been analysed through objective methods (Gastin et al., 2015; Jaspers et al., 2017), to our knowledge, no studies have examined the associations between initial physical fitness and the differential ratings of PE in TL and ML (i.e. dRPE TL or dRPE ML) in professional soccer players. Thus, knowing the association between initial physical fitness and the TL and ML assessed via subjective methods could be significant for those teams and technical staff lacking GPS/LPS sophisticated tools or HR monitors to assess TL and ML.

Therefore, the main purposes of the present study are to describe the physical fitness, along with the dRPE TL and dRPE ML assessment, of a Spanish professional soccer team at the beginning of the season and to analyse the associations between initial physical fitness and the dRPE TL or dRPE ML accumulated in several periods. Given that previous studies found a relevant association between physical fitness and external load (Castagna, Varley, Póvoas Araújo, & D'Ottavio, 2017; Malone et al., 2018), the initial hypothesis of the present study is that initial physical fitness could have a correlation with dRPE TL or dRPE ML.

## Methods

### *Participants*

Twenty male professional soccer players (27.1 ± 3.1 yr; 182.1 ± 4.6 cm; 76.5 ± 5.8 kg) from a team in the Spanish Second Division League took part in the study. The team trained 5–6 days per week in the morning or in the afternoon, with duration of 40–60 min per session. In addition to that, the team played in an official game each week. Training and rest days per week were classified depending on when matches took place. Thus the team typically trained on the second day after a match was disputed (match day [MD] minus 5; MD-5), followed by a day off and then four consecutive training sessions (MD-4, MD-3, MD-2 and MD-1) leading into the next match. For this research, data was only considered for those players who trained the whole week and played in that week's official match. The research was conducted according to the Declaration of Helsinki (2013) and received approval from the local Ethics Committee.

### *Design*

The study was performed during the pre-season (two weeks) and regular season competitive periods (six weeks). The participants were tested on the first training day of week 1 (Table 1). Training (TL) and match (ML) differentiated perceived (i.e. rating of respiratory and muscular exertion) load data (i.e. RPEres TL, RPEmus TL, RPEres ML and RPEmus ML) was collected from the physical fitness test session until the end of Week 8, in order to evaluate the associations between physical fitness performance level and accumulated TL and ML.

**Table 1.** Structuring of initial test, training and match sessions during the 8 weeks.

| | ***Monday*** | | ***Tuesday*** | | ***Wednesday*** | | ***Thursday*** | | ***Friday*** | | ***Saturday*** | | ***Sunday*** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AM | PM | AM | PM | AM | PM | AM | PM | AM | PM | AM | PM | AM | PM |
| **Week 1 (Pre-season)** | TeS | TS | TS | TS | - | FM (A) | TS | TS | TS | - | - | FM (H) | - | - |
| **Week 2 (Pre-season)** | TS | - | - | - | TS | TS | TS | - | TS | - | TS | - | - | OM (H) |
| **Week 3 (In-season)** | TS | - | - | - | TS | TS | TS | - | TS | - | TS | - | - | OM (A) |
| **Week 4 (In-season)** | TS | - | TS | TS | TS | - | TS | - | TS | - | - | OM (H) | - | - |
| **Week 5 (In-season)** | TS | - | TS | - | - | CupM (H) | TS | - | TS | - | - | OM (A) | - | - |
| **Week 6 (In-season)** | TS | - | TS | TS | TS | - | TS | - | TS | - | - | OM (H) | - | - |
| **Week 7 (In-season)** | TS | - | - | - | TS | TS | TS | - | TS | - | TS | - | - | OM (A) |
| **Week 8 (In-season)** | TS | - | - | - | TS | TS | TS | - | TS | - | TS | - | - | OM (H) |

TeS: test session; TS: training session; FM: Friendly match; OM: Official match; CupM: Cup match; H: home match; A: away match

***Methodology***

***Physical fitness assessment***

Before the testing session, players had a day off (24 h before) and a low-intensity training session (48 h before). Players performed a physical testing battery (30 m straight acceleration and an indirect continuous running multistage field test) on the morning of the first day of the sixth week of training, once they had already participated in 35 training sessions and played seven friendly matches during the pre-season. Before each testing session, a standardised warm-up was carried out.

***Acceleration speed***

Players performed two accelerations of 30 m in a straight line on a natural grass field, separated by 7 min passive rest. The run with the fastest time in 30 m was selected for further analysis. Velocity-time data for each sprint was collected via radar device (Morin and Sève, 2011) (Model: Stalker ATS II, Applied Concepts, Dallas, TX, USA) at 46.9 Hz, used to measure acceleration performance in soccer players (Samozino et al., 2014). The velocity-time data were used to determine the variables of interest of the sprint mechanical F-V profile according to Samozino et al. (2014), as well as sprint time to 5 and 30 m. The ratio of force was calculated as the ratio of the horizontally-oriented (antero-posterior) component to the total ground-reaction force (Morin et al., 2011). RFpeak corresponded to the maximal value of the ratio of force (at the very beginning of the acceleration phase), and the linear decrease in the ratio of force with velocity was calculated and presented as an index of the ability to maintain a high ratio of force throughout the acceleration phase (DRF) (Morin et al., 2011).

***Cardiovascular capacity***

In order to determine cardiovascular performance variables, the "Université de Montréal Tract Test" (UM-TT) (Léger & Boucher, 1980) was set up. Four soccer players did not take part in the test at the behest of the technical staff. Time to exhaustion (in min) and distance covered (in km) were considered for further analysis. The velocity (in $km \cdot h^{-1}$) of the last 1 min stage completed by the subjects was retained as the players' maximal aerobic speed (MAS). If the last stage was not completed entirely, the MAS was calculated using the formula of Kuipers et al. (1985): MAS = Sf + (t/60·0.5), where Sf was the last completed speed (in $km \cdot h^{-1}$) and t is the time (in s) of the uncompleted stage. The estimate $VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) was obtained using the formula of Léger & Boucher (1980): $VO_{2max} = 0.0324 \cdot x^2 + 2.143 \cdot x + 14.49$, being x the MAS (in $km \cdot h^{-1}$) reached by soccer players in the test. Finally, the anaerobic speed reserve (ASR) was calculated as follows: ASR ($km \cdot h^{-1}$) = MSS – MAS, where maximal sprinting speed (MSS) was defined as the fastest 10 m split time measured during a maximal 30 m acceleration (Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013).

***ML and TL quantification***

During the eight weeks the research lasted, professional soccer players carried out 46 training sessions in total, and played ten matches (two friendly matches during the pre-season, seven official league matches and a Spanish National King's Cup) (Table 1). During the pre-season, friendly matches were played in the middle of the week (Wednesday) and on the weekend (Saturday). During competitive period, official matches were played on the weekends (Second Division National League) and in the middle of the week (Spanish National King's Cup). The participants who played fewer minutes (substitutes and substitutive) in the official matches during the competition period performed a compensatory soccer training session immediately after the official match, which resulted in an increase of their weekly load.

In order to quantify TL and ML the differential ratings of perceived load (dRPE) method (Los Arcos, Martínez-Santos, Yanci, Mendiguchia, & Méndez-Villanueva, 2015a; Los Arcos, Méndez-Villanueva, Yanci, & Martínez-Santos, 2016; Weston et al., 2015) were used. This was performed ten min after each training and match session (Los Arcos et al., 2015a) and, using Foster's 0–10 scale (Foster et al., 2001), soccer players rated their perceived level of exertion separately for central-respiratory (i.e. RPEres) and leg local-muscular (i.e. RPEmus) effort (Los Arcos et al., 2015a, 2016; Weston et al., 2015). Both training and match respiratory and muscular perceived load (i.e. RPEres TL, RPEmus TL, RPEres ML and RPEmus ML) were calculated. The duration of a training or match session included recovery periods but excluded stretching, warm-up and half-time rest periods during match sessions (Los Arcos et al., 2015a, 2016; Weston et al., 2015).

***Statistical analysis***

Descriptive results are presented as means ± standard deviations (SD) and range. Inter-player variation for each variable was quantified by means of the coefficient of variation (CV). The distribution of the data was measured for each performance variable using the Shapiro-Wilk's normality test, which showed that data was not normally distributed. Therefore, in order to compare the results obtained between RPEres TL and RPEmus TL or RPEres ML and RPEmus ML in each of the training periods (i.e. 1–4, 5–8 and 1–8 week periods). Simultaneously, for the purpose of assessing the difference between 1–4 and 5–8 week periods for RPEres and RPEmus values in accumulated TL and ML, a Wilcoxon test was used. The practical differences were assessed by calculating the Cliff's Delta (Macbeth, Razumiejczyk, & Ledesma, 2011). The absolute value of the Cliff′s Delta can be considered small at around 0.15, medium at around 0.33, and large at around 0.47. The associations between initial (pretest) physical fitness performance variables and either TL or ML components were calculated with Spearman's correlation (r) and confidence limit was calculated at 95%. Data analysis was presented using the Statistical Package for Social Sciences (version 23.0 for Windows, SPSS® Inc, Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

## Results

Table 2 presents participants' performance and mechanical variables over the acceleration phase for professional soccer players in a 30 m straight acceleration test.

**Table 2.** 30 m straight acceleration performance and mechanical variables assessed over the acceleration phase for professional soccer players (n = 20).

| *Sprint variables* | *Mean ± SD* | *Range* | *Inter player CV (%)* |
|---|---|---|---|
| **$V_0$ ($m \cdot s^{-1}$)** | 9.03 ± 0.33 | 8.57 to 9.79 | 3.65 |
| **$F_0$ ($N \cdot kg^{-1}$)** | 7.10 ± 0.51 | 5.94 to 7.95 | 7.18 |
| **$P_{max}$ ($w \cdot kg^{-1}$)** | 15.92 ± 1.30 | 13.18 to 18.16 | 8.17 |
| **F-V profile** | -60.36 ± 7.83 | -78.31 to -46.64 | -12.97 |
| **Mean RF10 m (%)** | 0.31 ± 0.01 | 0.28 to 0.34 | 3.23 |
| **RF peak (%)** | 0.48 ± 0.02 | 0.43 to 0.52 | 4.17 |
| **DRF** | -0.07 ± 0.01 | -0.08 to -0.06 | -7.14 |
| **Time in 5 m (s)** | 1.40 ± 0.04 | 1.33 to 1.50 | 2.86 |
| **Time in 10 m (s)** | 2.15 ± 0.06 | 2.05 to 2.29 | 2.79 |
| **Time in 15 m (s)** | 2.81 ± 0.08 | 2.69 to 2.99 | 2.85 |
| **Time in 20 m (s)** | 3.44 ± 0.09 | 3.27 to 3.63 | 2.62 |
| **Time in 25 m (s)** | 4.04 ± 0.11 | 3.82 to 4.25 | 2.72 |
| **Time in 30 m (s)** | 4.63 ± 0.12 | 4.38 to 4.87 | 2.59 |
| **Distance in 2 sec (m)** | 8.80 ± 0.40 | 7.88 to 9.37 | 4.55 |
| **Distance in 4 sec (m)** | 24.51 ± 0.89 | 22.78 to 26.35 | 3.63 |
| **Top speed ($m \cdot s^{-1}$)** | 8.59 ± 0.29 | 8.18 to 9.29 | 3.38 |

$V_0$: theoretical maximal velocity; $F_0$: theoretical maximal force; $P_{max}$: horizontal external power; F-V profile: Force-velocity mechanical profile; RF: ratio of forces; DRF: index of force application technique; SD: standard deviation; CV: coefficient of variation.

Table 3 shows cardiovascular performance variables found in the indirect continuous running multistage field test (UM-TT) and the anaerobic speed reserve (ASR) for professional soccer players. The MAS and $VO_{2max}$ assessed of team (n = 16) were 16.43 ± 0.76 $km \cdot h^{-1}$ and 56.64 ± 2.72 $ml \cdot kg^{-1} \cdot min^{-1}$.

**Table 3**. Results from tests measuring the cardiovascular capacity of professional soccer players (n = 16) that participated in the indirect continuous running multistage field test (UM-TT).

| *Cardiovascular performance variables* | *Mean ± SD* | *Range* | *Inter player CV (%)* |
|---|---|---|---|
| **Exhaustion time (min)** | 21.32 ± 1.39 | 19.47 to 24.00 | 6.53 |
| **Distance covered (km)** | 6.03 ± 0.63 | 5.06 to 7.12 | 10.45 |
| **MAS ($km \cdot h^{-1}$)** | 16.43 ± 0.76 | 15.48 to 17.83 | 4.63 |
| **$VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)** | 56.64 ± 2.72 | 53.26 to 61.66 | 4.80 |
| **ASR ($km \cdot h^{-1}$)** | -14.28 ± 0.76 | -15.78 to -13.41 | -5.32 |

MAS: maximal aerobic speed; $VO_{2max}$: estimated maximal oxygen uptake; ASR: anaerobic speed reserve; UM-TT: Montreal University Track Test; SD: standard deviation; CV: coefficient of variation.

The results of ML and TL accumulated over several periods of the season (1–4, 5–8 and 1–8 week periods) for RPEres and RPEmus TL or ML are shown in Table 4. Significant differences were observed between 1–4 and 5–8 week periods for RPEres TL or RPEmus TL values ($p = 0.002$ and p = 0.016, Cliff's Delta = -0.15 – -0.40, from small to medium). Nevertheless, no significant differences were found for RPEres ML or RPEmus ML values ($p = 0.058$ and p = 0.085, Cliff's Delta = -0.25 – 0.31, medium) in similar time periods. Also, significant differences ($p = 0.002$ to p = 0.034, Cliff's Delta = -0.06 – -0.44, from small to medium) between RPEres and RPEmus data were found for ML and TL values within all periods (i.e. 1–8, 1–4 and 5–8 week periods).

**Table 4.** Match (ML) and training sessions (TL) differentiated perceived load (i.e. RPEres ML, RPEmus ML, RPEres TL, and RPEmus TL) accumulated in several training periods (1-4 weeks, 5-8 weeks and 1-8 weeks) for professional soccer players.

| | ***Accumulated ML*** | | | | ***Accumulated TL*** | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-8 weeks (N = 10 matches; 154 obser.) | 1-4 weeks (N = 5 matches; 81 obser.) | 5-8 weeks (N = 5 matches; 73 obser.) | Cliff's Delta, 1-4 weeks vs 5-8 weeks | 1-8 weeks (N = 46 training sessions; 980 obser.) | 1-4 weeks (N = 24 training sessions; 504 obser.) | 5-8 weeks (N = 22 training sessions; 476 obser.) | Cliff's Delta, 1-4 weeks vs 5-8 weeks |
| **RPEres (AU)** | 2761.74 ± 1848.95 (66.95) | 1279.83 ± 829.42 (64.81) | 1832.17 ± 1152.95 (62.93) | 0.31 (medium) | 6261.24 ± 1468.45 (23.45) | 3001.52 ± 529.97 (17.66) | 3390.22 ± 868.47 (25.62) | -0.40 (medium)# |
| **RPEmus (AU)** | 3008.80 ± 2080.50 (69.15) | 1403.67 ± 953.57 (67.93) | 1986.27 ± 1276.99 (64.29) | -0.25 (medium) | 6855.13 ± 1779.13 (25.95) | 3384.84 ± 808.20 (23.88) | 3617.46 ± 850.89 (23.52) | -0.15(small)# |
| **Cliff's Delta, – RPEres and RPEmus** | -0.11 (small)* | -0.35 (medium)* | -0.06 (small)* | | -0.25 (medium)* | -0.44 (medium)* | -0.22 (medium)* | |

Data are Mean ± SD (Inter player CV, %); ML: match load; TL: training load; SD: standard deviation; CV: coefficient of variation; Obser: observations; AU: Arbitrary units; RPEres: respiratory rating of perceived exertion; RPEmus: muscular rating of perceived exertion; *$p < 0.05$ significant differences between RPEres and RPEmus; #$p < 0.05$ significant differences between 1-4 and 5-8 week periods.

In line with the current association between initial physical fitness and ML, positive and significant large associations (from r = 0.50; ± 0.17 to r = 0.56; ± 0.11 95% CL, $p = 0.026$ *to* $0.049$) were found between initial MAS or $VO_{2max}$ and RPEmus ML in 1–4 and 1–8 week periods (Figure 1A, 1B, 1C and 1D). Conversely, negative and significant large associations (from r = -0.50; ± 0.17 to r = -0.55; ± 0.11 95% CL, $p$ = 0.049 and $p$ = 0.026) between ASR and RPEmus ML in 1–4 and 1–8 week periods were obtained. Thus, no significant associations (p = 0.62 to 0.144) between MAS, $VO_{2max}$ or ASR and RPEres ML were found. Likewise, no significant associations were found between acceleration capacity variables and dRPE ML (i.e. RPEres ML and RPEmus ML).

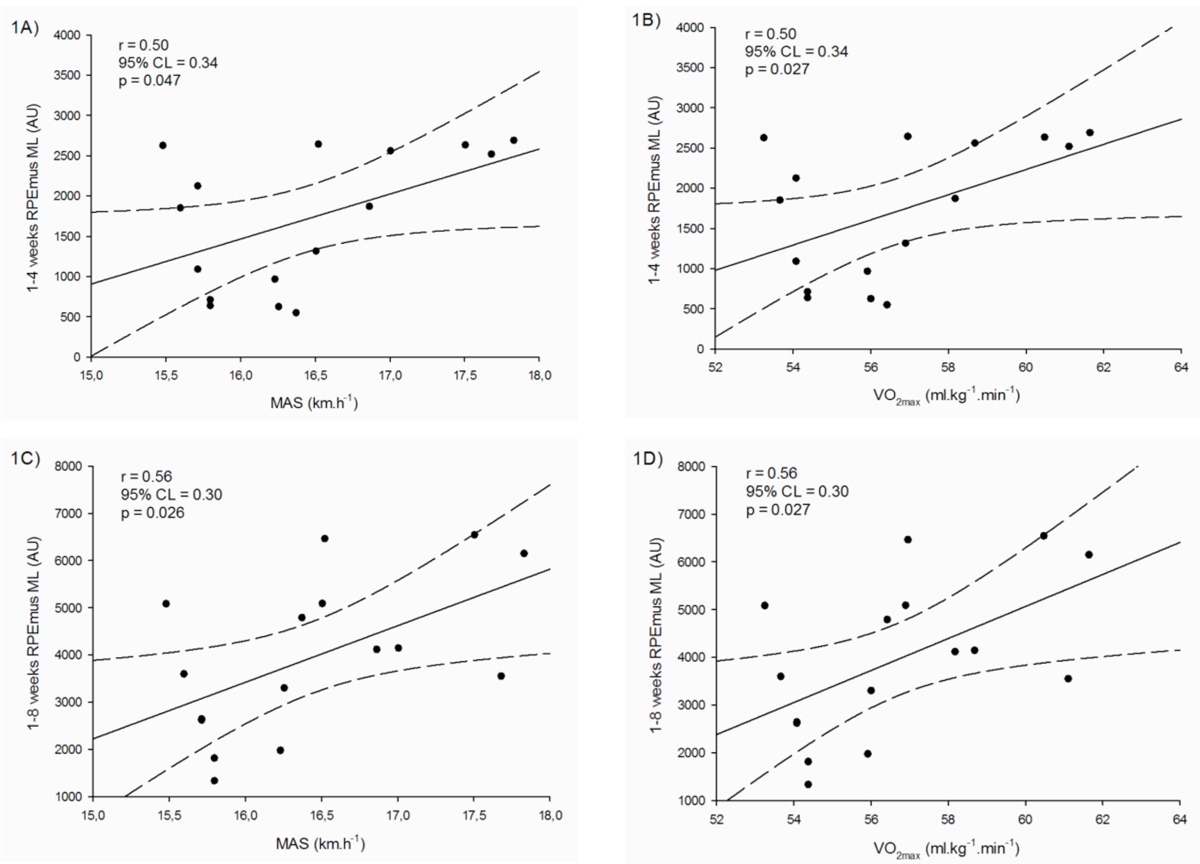


**Figure 1.** The relationship between MAS and RPEmus ML (1A), $VO_{2max}$ and RPEmus ML (1B) in 1–4 period, MAS and RPEmus ML (1C) and $VO_{2max}$ and RPEmus ML (1D) in 1–8 period.
MAS = maximal aerobic speed, $VO_{2max}$ = estimated maximal oxygen uptake, AU = arbitrary units, RPEmus ML = muscular session-rating of perceived exertion match load.

According to the association obtained between initial physical fitness and dRPE TL, in comparison to ML results, negative and significant large associations (from r = -0.53; ± 0.06 to r = -0.53; ± 0.05 95% CL, *p* = 0.035 to 0.036) were found between both MAS or $VO_{2max}$ and RPEres TL values throughout 5–8 and 1–8 week periods (Figure 2A, 2B, 2C and 2D). Conversely, positive and significant large associations (from r = 0.52; ± 0.07 95% CL, *p* = 0.038 to r = 0.52; ± 0.05 95% CL, *p* = 0.037) were described between ASR and RPEres TL at 5–8 and 1–8 week periods. Besides, no significant associations (*p* = 0.067 to 0.102) were found between MAS, $VO_{2max}$ or ASR and RPEmus TL, contrary to what happened during ML. Similarly, as the ML, no significant association was found between acceleration capacity variables and dRPE TL (i.e. RPEres TL and RPEmus TL).

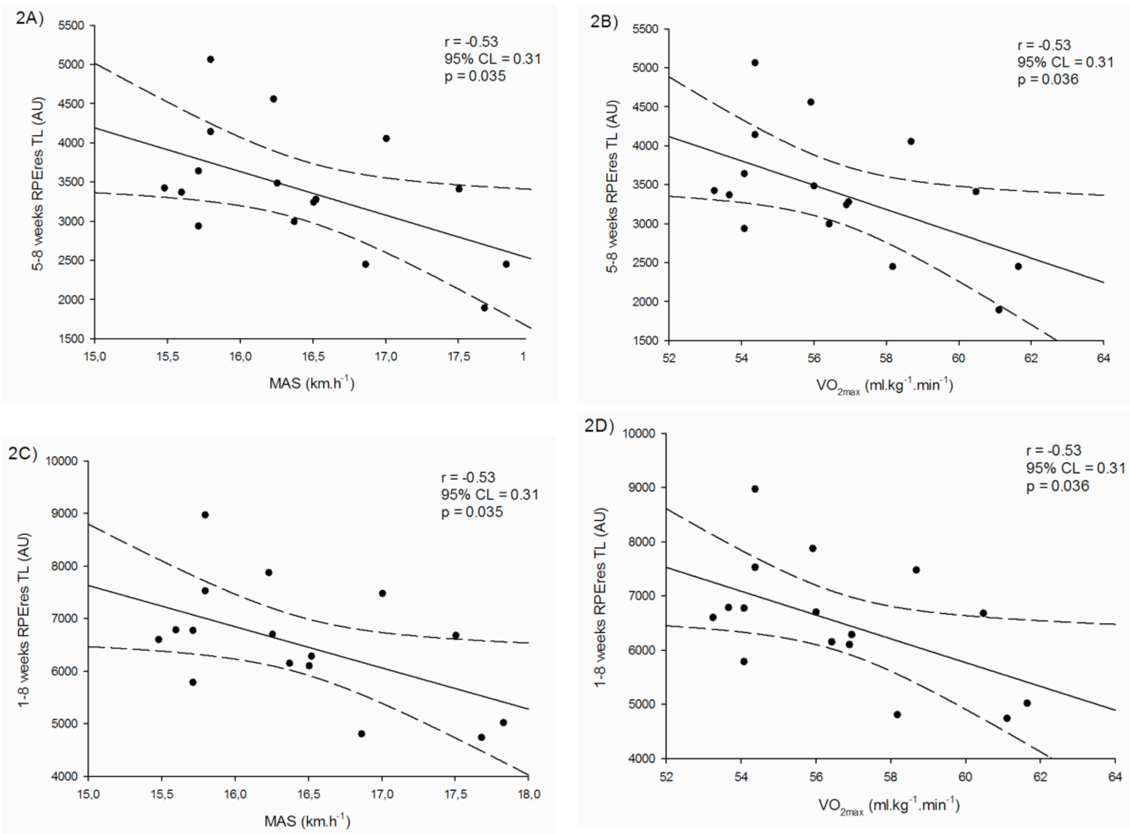


**Figure 2**. The relationship between MAS and RPEres TL (2A), $VO_{2max}$ and RPEres TL (2B) in 5-8 period, MAS and RPEres TL (2C) and $VO_{2max}$ and RPEres TL (2D) in 1-8 period.
MAS = maximal aerobic speed, VO2max = estimated maximal oxygen uptake, AU = arbitrary units, RPEres TL = respiratory sesssion-rating of perceived exertion training load.

## Discussion

The purpose of the present study was to describe physical fitness, along with the assessment of dRPE TL and dRPE ML of a Spanish professional soccer team at the beginning of the season and to analyse the associations between initial physical fitness and the dRPE TL or dRPE ML accumulated over several periods. The results obtained in this research, regarding the assessment of physical fitness during the season revealed that acceleration variables ($V_0$, $F_0$, $P_{max}$, F-V profile, and Top speed) showed better values than previous studies in no professional and amateur soccer players (Mendiguchia et al., 2015, 2014) but less successful than 48 international and national-level athletes (soccer players, sprinters and rugby players) (Samozino et al., 2014). Mendiguchia et al. (2014) provided lower acceleration values in 12 semi-professional male soccer players (i.e. $V_0 = 8.7 \pm 0.4$ m·s$^{-1}$, $F_0 = 7.1 \pm 0.7$ N·kg$^{-1}$, $P_{max} = 15.3 \pm 1.6$ w·kg$^{-1}$ and Top speed = $8.3 \pm 0.3$ m·s$^{-1}$) in comparison with the results obtained by the professional soccer players in the present study (i.e. $V_0 = 9.1 \pm 0.3$ m·s$^{-1}$, $F_0 = 7.1 \pm 0.5$ N·kg$^{-1}$, $P_{max} = 15.9 \pm 1.3$ w·kg$^{-1}$ and Top speed = $8.5 \pm 0.3$ m·s$^{-1}$). Furthermore, Mendiguchia et al. (2015) reported results, in amateur male soccer teams, that were in line with previous researches (Mendiguchia et al., 2014). The fact that players in the aforementioned studies compete at a lower competitive level (i.e. amateur vs. professional) could be the reason for a reduced acceleration capacity, not only regarding performance variables (i.e. time to cover a specific distance) but also in mechanical variables. Nevertheless, regarding cardiovascular performance assessed through the UM-TT, it remains unclear whether competitive category could be considered as one the factors that affect performance. This uncertainty is revealed by the fact that in Los Arcos et al. (2015b), younger players in a lower competitive category (male soccer players under the age of 16 who competed in a Spanish First Division club academy) showed MAS values similar to those obtained in the present research, which was carried out with professional soccer players in the Spanish Second Division League ($16.8 \pm 0.9$ vs. $16.4 \pm 0.8$ km·h$^{-1}$). Conversely, other studies (Buchheit, Simpson, & Mendez-Villanueva, 2012) showed results in youth soccer players that differed from ours. Castillo et al. (2018) showed that N-S team players of an elite soccer academy promoted to the Spanish First or Second Division did not obtain better aerobic capacity values than players who did not achieve promotion to these categories. However, Rampinini et al. (2007) reported better cardiovascular performance values in professional top-level soccer players in one of the most important European leagues, which placed in the top four of the final rankings (MAS = 17.7 ± 0.9 $km \cdot h^{-1}$), than the one observed in this research (MAS = 16.4 ± 0.8 $km \cdot h^{-1}$). Similarly, Rosch et al. (2000) reported lower cardiovascular performance in amateur players compared to top-level and Third Division players in different endurance tests. It seems that top-level players have a higher aerobic capacity than amateur and younger players, but at lower levels of professional competition, the differences are less clear. In fact, comparisons among studies dealing with these aspects at different competitive levels are difficult to make due to the various test protocols, different methods used and test implementation times. Therefore, further studies are necessary in order to find out whether physical fitness (i.e. sprinting acceleration and cardiovascular capacity test) discriminates depending on competitive level or age group (i.e. senior instead of young soccer players).

The results of the present study show significant differences between RPEres TL and RPEmus TL or between RPEres ML and RPEmus ML values in the different time frames analysed. Furthermore, higher RPEmus than RPEres values were found for all the session periods (both TL or ML). Likewise, Weston et al. (2015) observed higher RPEmus than of RPEres scores in Australian Football League matches. These results were also in line with prior observations of more local-peripheral sensations being perceived than central-chest sensations during match sessions among Spanish male professional soccer players who played more than 45 min or 70 min (Los Arcos et al., 2016). Despite the fact that Los Arcos et al. (2016) found that the differences between the respiratory and muscular ratings of PE were trivial in most cases, the results obtained by the present research would seem to indicate that both, training sessions and matches, could have a more significant neuromuscular implication. The differences found, may be due to the fact that accumulated load, in this case, was considered over longer periods of time (i.e. several weeks, included training and match sessions) compared to other studies. The high values of RPEmus TL and RPEmus ML observed in this research may be caused by the high number of short high-intensity actions produced over the course of a soccer game (Buchheit et al., 2012), where strength has a significant implication. As observed by other researchers, this important neuromuscular implication creates significant muscle fatigue, expressed by a loss of physical fitness after the conclusion of the matches played (Buchheit et al., 2012). Because soccer involves great neuromuscular involvement, it might be necessary to carry out training sessions focusing on strength. In addition, it would also be advisable to supplement these sessions with appropriate post-match or post training-session recovery programs in this capacity.

In addition, it should be noted that another interesting finding of this research was that, both RPEres TL and RPEmus TL, showed higher values over a 5–8 week period than over a 1–4 week period. Although Malone et al. (2015) found no RPE differences during the first weeks of training, they did observe a higher total distance covered in training sessions as the season advanced and recorded the highest HR response at the midpoint of the season. Considering that the results of our research do not enable definite conclusions that would confirm whether an increase of dRPE TL over 5–8 week periods was due to a change in training strategies or greater physical fatigue in players, it would be interesting to know the reasons for that rise in dRPE TL.

Given the fact that Jaspers et al. (2017), in a recent systematic review, concluded that soccer players with low physical fitness showed an increase in their internal load during the season, this information sheds light on the possibility that training sessions may result in a greater internal load for those players with lower physical fitness, and consequently, a higher amount of accumulated fatigue. As a result, the importance of initial physical fitness to the internal load in match and training sessions is revealed. In our study, positive and large associations were found between initial MAS or $VO_{2max}$ and RPEmus ML, along with negative and large significant associations between ASR and RPEmus ML in 1–4 and 1–8 week periods. Furthermore, negative and large significant associations were found between both MAS or $VO_{2max}$ and RPEres TL values, just as positive and large associations between ASR and RPEres TL throughout 5–8 and 1–8 week periods. Thus, players with better initial cardiovascular capacity displayed a higher RPEmus ML in several periods (i.e. 1-4 and 1-8 week periods) and a lower RPEres TL in 5-8 and 1-8 week periods. Thus, soccer players with better cardiovascular capacity are able to deal, on the one hand, with a high level of muscular load in matches and, on the other hand, to perceive a low level of respiratory effort in training sessions. Considering that, firstly, high TL is associated with a significantly higher risk of injury in soccer players (Bowen et al., 2017), and secondly, taking into account the positive factor that players who are able to support higher RPEmus ML may be related to a greater external load performed in a match (Jaspers et al., 2017; Matthew Weston et al., 2015) instead of being appropriately managed by the player from a technical and tactical perspective to improve their competitive performance, it would be of great interest to soccer technical staff focused on improving cardiovascular capacity.

Despite the novel data presented dealing with the association between initial physical performance, dRPE TL and dRPE ML in the current study, there are some limitations that should be mentioned. The sample for this study was of convenience and with a reduced sample size, primarily because the goal of this study was to take professional players into account. Furthermore, workload generated in previous stages (i.e. at the beginning of the pre-season) was not considered, and this is an aspect that could have influenced the results. Another limitation is that the study was restricted by the number of contextual variables available for analysis, as, for instance, the impact of opposition and playing at home or away, among others, considering that these variables can sometimes influence the ML (Brito et al., 2016; Bush et al., 2015). In addition, the study did not show quantified data through external load. Therefore, it would be interesting to analyse this aspect in future research.

**Practical Implications**

This research provides useful information relating to the TL and ML employed by a professional soccer team. For coaches and practitioners, our data also highlight the importance of monitoring internal load during matches and training sessions throughout the dRPE to help manage workloads and prescribe appropriate training and recovery activities. dRPE could be a useful tool for monitoring changes in training and match sessions and, finally, implementing specific post-match recovery strategies throughout the season.

**Conclusions**

The results of this research showed higher RPEmus than RPEres both in TL and ML, indicating that training sessions and soccer matches produce a large involvement to neuromuscular performance. Furthermore, a 5–8 week period showed higher dRPE TL values than a 1–4 week period. Further research is needed to find out whether these differences are due to players' higher levels of fatigue or to a change in the training sessions performed. Conversely, positive and large significant associations between cardiovascular capacity in RPEmus ML, along with negative and large significant associations between cardiovascular capacity in RPEres TL values, were obtained. This fact leads us to infer that better cardiovascular capacity could be linked with a lower RPEres TL and higher RPEmus ML.

**Acknowledgements**

The authors would like to thank the team's coaches and players for their cooperation during all data-collection procedures and for the opportunity to carry out this investigation.

## References

Abbott, W., Brickley, G., Smeeton, N. J., & Mills, S. (2018). Individualizing acceleration in English Premier League academy soccer players. *Journal of Strength and Conditioning Research*, *32*(12), 3503–3510.

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 Science*, *34*(24), 2205–2214.

Anderson, L., Orme, P., Di Michele, R., Close, G. L., Milsom, J., Morgans, R., Drust, B., & Morton, P. (2016). Quantification of seasonal long physical load in soccer players with different starting status from the English Premier League: Implications for maintaining squad physical fitness. *International Journal of Sports Physiology and Performance*, 11(8), 1038–1046.

Beato, M., Jamil, M., & Devereux, G. (2018). Reliability of internal and external load parameters in recreational football (soccer) for health. *Research in Sports Medicine*, 26(2), 244–250.

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.

Bradley, P. S., Di Mascio, M., Peart, D., Wooster, B., Olsen, P., & Sheldon, B. (2010). High-Intensity activity profiles of elite soccer players at different performance levels. *Journal of Strength and Conditioning Research*, 24(9), 2343–2351.

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.

Buchheit, M., Simpson, B. M., & Méndez-Villanueva, A. (2012). Repeated high-speed activities during youth soccer games in relation to changes in maximal sprinting and aerobic speeds. *International Journal of Sports Medicine*, 34(1), 40–48.

Bush, M. D., Archer, D. T., Hogg, R., & Bradley, P. S. (2015). Factors influencing physical and technical variability in the english premier league. *International Journal of Sports Physiology and Performance*, *10*(7), 865–872.

Castagna, C., Varley, M., Póvoas Araújo, S. C., & D'Ottavio, S. (2017). The evaluation of the match external load in soccer: methods comparison. *International Journal of Sports Physiology and Performance*, *12*(4), 490–495.

Castillo, D., Los Arcos, A., & Martínez-Santos, R. (2018). Aerobic endurance performance does not determine the professional career of elite youth soccer players. *Journal of Sports Medicine Physiology Fitness*, 58(4), 392–398.

Clemente, F. M., Sarmento, H., Rabbani, A., Van Der Linden, C. M. I. N., Kargarfard, M., & Costa, I. T. (2019). Variations of external load variables between medium- and large-sided soccer games in professional players. *Research in Sports Medicine*, 27(1), 50–59.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research,* 15(1), 109–115.

Gastin, P. B., Meyer, D., Huntsman, E., & Cook, J. (2015). Increase in injury risk with low body mass and aerobic-running fitness in elite Australian football. *International Journal of Sports Physiology and Performance*, 10(4), 458–463.

Geurkink, Y., Vandewiele, G., Lievens, M., De Turck, F., Ongenae, F., Matthys, S. P. J., Boone, J., & Bourgois, J. G. (2019). Modeling the prediction of the session rating of perceived exertion in soccer: unraveling the puzzle of predictive indicators. *International Journal of Sports Physilogy and Performance*, *24*, 1–6.

Jaspers, A., Brink, M. S., Probst, S. G., Frencken, W. G., & Helsen, W. F. (2017). Relationships between training load indicators and training outcomes in professional soccer. *Sports Medicine,* 47(3), 533–544.

Jaspers, A., Kuyvenhoven, J. P., Staes, F., Frencken, W. G. P., Helsen, W. F., & Brink, M. S. (2018). Examination of the external and internal load indicators' association with overuse injuries in professional soccer players. *Journal of Science and Medicine in Sport*, *21*(6), 579–585.

Kuipers, H., Verstappen, H., Keizer, P., & Van Kranenburg, G. (1985). Variability of aerobic performance in the laboratory and its physiologic correlates. *International Journal of Sports Medicine,* 6(4), 197–201.

Léger, L., & Boucher, R. (1980). An indirect continuous running multistage field test: the Université de Montréal track test. *Canadian Journal of Applied Sport Sciences. Journal Canadien Des Sciences Appliquees Au Sport*, 5(2), 77–84.

Los Arcos, A., Martínez-Santos, R., Yanci, J., Mendiguchia, J., & Méndez-Villanueva, A. (2015a). Negative associations between perceived training load, volume and changes in physical fitness in professional soccer players. *Journal of Sports Science and Medicine,* 14(2), 394–401.

Los Arcos, A., Méndez-Villanueva, A., Yanci, J., & Martínez-Santos, R. (2016). Respiratory and muscular perceived exertion during official games in professional soccer players. *International Journal of Sports Physiology and Performance,* 11(3), 301–304.

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., & Zulueta, J. J. (2015b). Effects of small-sided games vs. interval training in aerobic fitness and physical enjoyment in young elite soccer players. *PLoS One*, 10(9).

Macbeth, G., Razumiejczyk, E., & Ledesma, R. (2011). Cliff's Delta Calculator : A non-parametric effect size program for two groups of observations. *Universitas Psychologica*, *10*(2), 545–555.

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

Malone, S., Owen, A., Mendes, B., Hughes, B., Collins, K., & Gabbett, T. J. (2018). High-speed running and sprinting as an injury risk factor in soccer: Can well-developed physical qualities reduce the risk?. *Journal of Science and Medicine in Sport*, 21(3), 257–262.

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.

McMorrow, B. J., Ditroilo, M., & Egan, B. (2019). Effect of heavy resisted sled sprint training during the competitive season on sprint and change-of-direction performance in professional soccer players. *International Journal of Sports Physilogy and Performance*, *31*, 1–25.

Méndez-Villanueva, A., Buchheit, M., Simpson, B., & Bourdon, P. C. (2013). Match play intensity distribution in youth soccer. *International Journal of Sports Medicine*, 34(2), 101–110.

Mendiguchia, J., Edouard, P., Samozino, P., Brughelli, M., Cross, M. R., Ross, A., Gill, N. D., & Morin, J. B. (2016). Field monitoring of sprinting power-force- velocity profile before, during and after hamstring injury: two case reports. *Journal of Sports Science*, 34(6), 535–541.

Mendiguchia, J., Martínez-Ruiz, E., Morin, J. B., Samozino, P., Edouard, P., Alcaraz, P.

E., Esparza-Ros, F., & Méndez-Villanueva, A. (2015). Effects of hamstring-emphasized neuromuscular training on strength and sprinting mechanics in football players. *Scandinavian Journal of Medicine and Science in Sports*, 25(6), 621–629.

Mendiguchia, J., Samozino, P., Martínez-Ruiz, E., Brughelli, M., Schmikli, S., Morin, J. B., & Mendez-Villanueva A. (2014). Progression of mechanical properties during on-field sprint running after returning to sports from a hamstring muscle injury in soccer players. *International Journal of Sports Medicine*, *35*(8), 690–695.

Morcillo, J. A., Jiménez-Reyes, P., Cuadrado-Peñafiel, V., Lozano, E., Ortega-Becerra, M., & Párraga, J. (2015). Relationships between repeated sprint ability, mechanical parameters, and blood metabolites in professional soccer players. *Journal of Strength and Conditioning Research*, 29(6), 1673–1682.

Morin, J. B., Edouard, P., & Samozino, P. (2011). Technical ability of force application as a determinant factor of sprint performance. *Medicine and Science in Sports and Exercise*, 43(9), 1680–1688.

Morin, J. B., & Sève, P. (2011). Sprint running performance: Comparison between treadmill and field conditions. *European Journal of Applied Physiology*, 111(8), 1695–1703.

Oliveira, R., Brito, J., Martins, A., Mendes, B., Calvete, F., Carriço, S., Ferraz, R., & 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*, 146–156.

Rampinini, E., Bishop, D., Marcora, S. M., Ferrari-Bravo, D., Sassi, R., & Impellizzeri F. M. (2007). Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *International Journal of Sports Medicine*, 28(3), 228–235.

Rosch, D., Hodgson, R., Peterson, T. L., Graf-Baumann, T., Junge, A., Chomiak, J., & Dvorak, J. (2000). Assessment and evaluation of football performance. *American Journal of Sports Med*icine, 28(5), S29–S39.

Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Love, T. D., Bracken, R. M., & Kilduff, L. P. (2016). Changes in acceleration and deceleration capacity throughout professional soccer match-play. *Journal of Strength and Conditioning Research*, *30*(10), 2839–2844.

Samozino, P., Edouard, P., Sangnier, S., Brughelli, M., Gimenez, P., & Morin, J. (2014). Force-velocity profile: Imbalance determination and effect on lower limb ballistic performance. *International Journal of Sports Medicine*, 35(6), 505–510.

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. Sports Medicine (Vol. 48). *Springer International Publishing.*

Tang, R., Murtagh, C., Warrington, G., Cable, T., Morgan, O., O'Boyle, A., Burgess, D., Morgans, R., & Drust, B. (2018). Directional change mediates the physiological response to high-intensity shuttle running in professional soccer players. *Sports*, *6*(2), 39.

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2016). Tracking morning fatigue status across in-Season training weeks in elite soccer players. *International Journal of Sports Physiology and Performance*, *11*(7), 947–952.

Weston, M., Siegler, J., Bahnert, A., McBrien, J., & Lovell, R. (2015). The application of differential ratings of perceived exertion to Australian Football League matches. *Journal of Science and Medicine in Sport,* 18(6), 704–708.

# Subchapter 3.3. Paper 3

# Differentiated perceived match load and its variability according to playing position in professional soccer players during an entire season

Unai Azcárate, Javier Yanci & Asier Los Arcos

*Kinesiology*, 2019, (in press).

# Subchapter 3.3. Paper 3

## Differentiated perceived match load and its variability according to playing position in professional soccer players during an entire season

Unai Azcárate[1], Javier Yanci[1], Asier Los Arcos[1]

[1]*Physical Education and Sport Department, Faculty of Education and Sport, University of the Basque Country, UPV/EHU, Vitoria-Gasteiz, Spain.*

**Abstract**

The aims were to assess differentiated perceived match exertion and its variability according to playing position for professional soccer players. 19 Spanish players declared their respiratory and muscular perceived exertions (PEs) after official matches during an entire season. Players were classified according to their playing position. In order to assess differentiated perceived match exertion, soccer players were asked to assess their perceived level of exertion following each official match. Considerable differences ($p < 0.05$; ES = 0.41 - 2.49) were found between some playing positions but not always in both dimensions of PE (respiratory and muscular). Advanced midfielders (AvMs), wide midfielder (WMs) and wing backs (WnBs) reported the highest match respiratory PE and muscular PE scores. Furthermore, match-to-match differentiated perceived match exertion variability ranged from 12.8 to 27.7% for respiratory PE and from 11.5 to 25.2% for muscular PE according to playing position. Match respiratory-muscular PE differences varied among the playing positions, showing higher muscular PE than respiratory PE in central backs (CBs), WMs and central midfielders (CMs) ($p < 0.05$; ES = -0.35 to 0.68), but higher respiratory PE than muscular PE in wing backs ($p < 0.05$; ES = -0.35). Soccer differentiated perceived match exertion is different inter and intra some playing positions, showing large swings for match-to-match variability between playing positions. These facts confirm that the deconstruction of the overall PE provides a more accurate evaluation of the subjective match internal load in some playing positions.

***Keywords**:* quantification; football; differentiated perceived effort; variation; posts.

## Introduction

With classification points on the line, official matches are the most important session of week during the 9–10 consecutive months that the competitive season lasts. Moreover, matches are, for ST, the most demanding physical/physiological sessions of the week for ST (Anderson et al., 2016; Arcos et al., 2014; Los Arcos et al., 2017); disrupting the levels of muscle-injury markers, inflammation and immunological cell tracking, impairs physical performance and exacerbates perceptual responses until, at least, 72 h after a match is played (Silva et al., 2018). Thus, weeks turn into the periodization unit of professional soccer coaches. Taking previous and future matches as a reference, professional soccer coaches design recovery sessions for starting players at the beginning of the week (Gaudino et al., 2015; Loturco et al., 2016; Malone et al., 2015), plan training activities to attain the highest weekly TL in the middle of the week (Los Arcos et al., 2017; Malone et al., 2015; Stevens et al., 2017) and reduce physiological and physical demands in training sessions prior to a match (Los Arcos et al., 2017; Malone et al., 2015; Thorpe et al., 2015), in order to prepare players for the competition and avoid pre-match fatigue. During weeks when two matches were played, the internal TL of training sessions was reduced in comparison to weeks with one match, signaling the importance that recovery strategies have in the former (Clemente et al., 2017) for players to be at their top physical shape in each match. As a consequence, the weekly TL varies slightly during the competitive period of the season (Los Arcos et al., 2017; Loturco et al., 2016; Malone et al., 2015) beyond the length of the between-match microcycles (Azcárate et al., 2018).

Several systematic reviews (Saw, Main, & Gastin, 2016; Silva et al., 2018) have suggested that subjective measures are appropriate in order to assess the levels of stress derived from competing. However, while many researches have described external and internal ML measured with objective methods, only a few have quantified internal ML via players' subjective assessments in high-level soccer matches (i.e. match perceived exertion [PE]) (Arcos et al., 2014; Barrett et al., 2018; Fessi & Moalla, 2018; Los Arcos et al., 2016). Recently, due to the substantial differences found between match respiratory PE (PEres) and muscular PE (PEmus) in Spanish young professional soccer players (Los Arcos et al., 2016) and in Australian Football League players (Weston, Siegler, Bahnert, McBrien, & Lovell, 2015), differential PE (dPE) has been suggested for the assessment of match-imposed internal ML (Los Arcos et al., 2016; McLaren, Weston, Smith, Cramb, & Portas, 2015; Weston et al., 2015) because these measures represent distinct sensory inputs and provide a more accurate evaluation than overall PE (Weston et al., 2015). However, the distinction between respiratory and muscular exertions has been used to quantify internal ML in high level soccer (Arcos et al., 2014; Barrett et al., 2018; Los Arcos et al., 2016).

Despite the fact that playing positions determine the external ML of high level soccer players (Castellano, Álvarez-Pastor, & Bradley, 2014; Sarmento et al., 2018; Sarmento et al., 2014), to our knowledge, only one study has evaluated the impact of playing positions on professional soccer match dPE (Barrett et al., 2018). English Premier League Full Backs reported higher dPE scores than all other playing positions (Barrett et al., 2018). Moreover, several studies have found large match-to-match variability (coefficient of variation [CV]), from 10.7 to 32.3%, for high-intensity-running variables of velocity covered during a match in professional soccer players (Bush, Archer, Hogg, & Bradley, 2015; Carling, Bradley, Mccall, & Dupont, 2016; Gregson, Drust, Atkinson, & Salvo, 2010), and they also reported considerable differences between playing positions (Bush et al., 2015; Carling, Bradley, McCall, et al., 2016; Gregson et al., 2010). As far as we are concerned, only a study has assessed dPE variability in professional soccer, showing that this variability ranged from 14 to 54% depending on the playing time, being lower the longer the players played (Los Arcos et al., 2016). However, no study has assessed match-to-match dPE variability of professional soccer players according to their playing position.

Therefore, the main aim of this study was to assess dPE ML and its variability according to playing position for Spanish professional soccer players during an entire season.

## Methods

### *Participants*

Match dPE (i.e. PEres and PEmus) data were collected from nineteen male outfielders playing professional soccer (27.8±3.1 years; 181.8±3.3 cm; 76.1±5.1 kg) belonging the same Spanish Second Division League team during the 2015–2016 season. Goalkeepers were excluded from the study. The participants gave informed consent to take part in this study. The research was conducted according to the Declaration of Helsinki (2013) and received approval from the local Ethics Committee.

***Procedures***

In order to assess dPE ML, soccer players were asked to assess their perceived level of exertion in the ten min following each official match (Los Arcos et al., 2015) using Foster's 0–10 scale (Foster et al., 2001) and by the same person every time (i.e. fitness coach). This was done for central-respiratory (PEres) and local-muscular (PEmus) effort (Los Arcos et al., 2016; Weston et al., 2015). Players responded to two simple questions on a unique evaluation sheet and always in the same order: How hard was your session on your chest? And how hard was your session on your legs? Each player completed the 0–10 scale randomly without the presence of other players and they could not see the values of other participants. All players became familiarized with this method during the pre-season match period (8 weeks, from July 9 to August 22), in both training sessions and friendly matches. The playing time for each match was recorded for each player, excluding warm-up and half-time rest periods (Los Arcos et al., 2016; Yanci et al., 2014).

***Design***

During the data collection process, players trained 5–6 times (a.m. and/or p.m.) and participated in 1–2 matches (league and cup) per week from the end of August to the beginning of May. PEres and PEmus ML was recorded according to the position of players who played the entire match (i.e. central back [CB], wide back [WB], wing back [WnB], wide midfielder [WM], central midfielder [CM], advanced midfielder [AvM] and striker [S]). Matches in which outfielders participated <90 min (i.e. substitute and substituted players) were excluded from the study. Furthermore, matches in which players switched positions throughout the match (i.e. mixed position) were also excluded. The team used the same tactical system in all matches (1–3–4–3). Matches in which one or more players were sent off were not included in this research. In total, 44 official matches were considered for data analysis: 22 "home" matches, out of which 4 were cup and 18 were league matches, and 22 "away" matches, comprising 3 cup and 19 league matches. A total of 331 individual PE ratings (M 17, range 2–34 observations per player) were obtained from 44 of the 50 official matches disputed from team in the season (i.e. 36 of the 42 league matches and 7 of the 8 King's Cup matches), with the following occurrences for each playing position: CB position, 40 occurrences from 3 players; WB position, 79 occurrences from 6 players; WnB position, 55 occurrences from 7 players; WM position, 51 occurrences from 6 players; CM position, 33 occurrences from 2 players; AvM position, 19 occurrences from 5 players; and S position, 11 occurrences from 4 players.

***Statistical analysis***

Data are expressed as mean ± standard deviation (SD). For each playing position, match-to-match variability in PEres and PEmus was expressed using the coefficient of variation (CV; %) (Atkinson & Nevill, 1998). Additionally, the distribution of the data was measured for each playing position using the Kolmogorov-Smirnov normality test, which showed that data was not normally distributed. The Kruskal-Wallis test and Mann-Whitney U test were used to analyze the between-position comparison regarding intra- and inter-playing position for PEres and PEmus in each case, respectively. Furthermore, intra- and inter-playing position practical differences in PEres and PEmus were assessed by calculating the Cohen's d effect size (Cohen, 1988). Effect sizes (ESs) of higher than 0.8, 0.8 – 0.5, 0.5 – 0.2 and lower than 0.2 were considered large, moderate, small and trivial, respectively. The data analysis was presented using the Statistical Package for Social Sciences (version 23.0 for Windows, SPSS® Inc., Chicago, IL, USA). The level of statistical significance was set at $p < 0.05$.

**Results**

In general, players assessed the dPE of the official match to be "hard" for PEres (6.5 ± 0.9) and for PEmus (6.8 ± 0.8), with a match-to-match variability of 13.5 and 11.8% for PEres and PEmus, respectively.

According to playing position, dPEs of all official matches ranged from "hard" to "very hard" for PEres (5.4 ± 1.2 to 7.7 ± 1.1) and for PEmus (5.8 ± 0.9 to 8.1 ± 0.9), with a CV from 12.8 to 27.7% for PEres and 11.5 to 25.2% for PEmus (Table 1). The match dPE differences between some playing positions varied according to the dimension of PE assessed.

**Table 1.** Match respiratory and muscular perceived exertions (i.e. PEres and PEmus), between-positions comparison and its match-to-match variability according to the playing position.

| | *CB* | *WB* | *WnB* | *WM* | *CM* | *AvM* | *S* | *Differences (p and ES) between PPs* |
|---|---|---|---|---|---|---|---|---|
| **Occ.** | 40 | 79 | 55 | 51 | 33 | 19 | 11 | |
| **PEres** | 5.8 ± 0.8 | 6.2 ± 1.1 | 7.4 ± 1.3 | 7.4 ± 1.2 | 5.4 ± 1.2 | 7.7 ± 1.1 | 6.3 ± 1.7 | CB-WB-S<AvM$^{l(all)**}$-WM$^{m(S)*,l(CB-WB)**}$-WnB$^{m(S),*l(CB-WB)**}$ |
| ***CV (%)*** | *12.8* | *18.3* | *17.0* | *16.6* | *22.6* | *13.7* | *27.7* | CM<CB$^{s**}$-WB$^{m**}$ |
| | | | | | | | | S<WnB$^{m*}$/WM$^{m*}$/AvM$^{l**}$ |
| **PEmus** | 6.5 ± 1.0 | 6.2 ± 1.2 | 7.0 ± 1.3 | 8.1 ± 0.9 | 5.8 ± 0.9 | 7.8 ± 1.1 | 6.8 ± 1.7 | CB-WB<WnB$^{s(CB)*,m(WB)**}$<AvM$^{l(CB-WB)**,m(WnB)**}$-WM$^{l(CB-WB)**,l(WnB)**}$ |
| ***CV (%)*** | 15.2 | 19.1 | 18.2 | 11.5 | 15.2 | 13.9 | 25.2 | CM<CB$^{m**}$/WnB$^{l**}$/WM$^{l**}$/AvM$^{l**}$/S$^{m*}$ |
| | | | | | | | | S<WM$^{l**}$ |

*CB* = Central Back*; WB* = Wide back*; WnB* = Wing back*; WM* = Wide midfielder*; CM* = Central midfielder*; AvM* = Advanced midfielder*; S* = Striker; ES = Effect Size; PPs = playing positions; Occur = occurrences; PEres = rating of central-respiratory perceived exertion; PEmus = rating of local-muscular perceived exertion; CV = coefficient of variation; - = no significant differences; > = significantly higher; < = significantly lower. * = $p < 0.05$; ** = $p < 0.001$; s = small ES; m = moderate ES; l = large ES

Considering all players together, significant and substantial differences ($p < 0.05$, ES = small) were found between PEres and PEmus, though these differences varied (i.e. significance, magnitude and sign) according to playing position (Table 2).

**Table 2.** Respiratory (PEres) vs muscular (PEmus) match PE differences by playing position.

| ***Playing Positions*** | ***PEres vs. PEmus*** | |
|---|---|---|
| | *ES* | *Qualitative interpretation* |
| **All players** | *0.35** | *Small* |
| **Central back** | 0.66* | Moderate |
| **Wide back** | 0.06 | Trivial |
| **Wing back** | -0.35* | Small |
| **Wide midfielder** | 0.68* | Moderate |
| **Central midfielder** | 0.46* | Small |
| **Advanced midfielder** | 0.11 | Trivial |
| **Striker** | 0.32 | Small |

ES = effect size; * significant differences ($p < 0.05$) between PEres and PEmus.

## Discussion and conclusions

The main aim of the present study was to compare between-position and intra-playing position match PEres and PEmus for Spanish professional soccer players who participated in entire official matches. The main findings were: (1) Soccer match exertion (i.e. “hard”–“very hard”) was different (ES = small–large) between some playing positions, but not always in both dimensions of PE (i.e. respiratory and muscular); (2) AvMs, WMs and WnBs reported the highest PEres and PEmus scores; (3); the variability of playing position match-to-match dPE ranged from 12.8 to 27.7% for PEres and from 11.5 to 25.2% for PEmus, with the highest match dPE variability for CMs (CV = 15.2 – 22.6%) and for Ss (CV = 25.2 – 27.7%); and (4) the dimensions of PE are demanded in different ways and at different levels for some playing positions. Therefore, the deconstruction of the overall PE (i.e. PEres and PEmus) provides a more accurate evaluation of the subjective match internal load for some playing positions, showing substantial between-position and intra-playing position differences according to the dimension of PE assessed.

Taking together all players, the Spanish Second Division professional soccer players rated all official matches as "hard" (PEres = 6.5 ± 0.9 and PEmus = 6.8 ± 0.8). Similarly, young professional soccer players who competed in the Spanish 2nd Division B rated the official match (i.e. >90 min) as "hard", almost "very hard", after the differentiation between PEres (6.7 ± 1.3) and PEmus (6.9 ± 1.6) (Los Arcos et al., 2016). Moreover, Stars League professional soccer players perceived the official match as "hard" to "very hard" (~6.5) using overall PE (M. S. Fessi & Moalla, 2018). However, elite junior soccer players reported a higher overall PE (8.4 ± 1.3, "very hard") than professional soccer players after official matches (Wrigley et al., 2012). These results suggest that the perceived match exertion is "hard", almost "very hard" in professional soccer players but lower in comparison to junior soccer players. In accordance with the match-to-match variability, dPE was 13.5% for PEres and 11.8% for PEmus for all players. These values were lower than the variability described by Los Arcos et al. (2016) in young professional soccer players of an elite reserve team (PEres, CV = 18.2 ± 6.2%; PEmus, CV = 19.4 ± 9.3%), suggesting that in addition to the length of the match, shorter playing times were associated with greater variability (54% for <20-min group and 14% for >70-min group), competition level also affects the variability of the perceived match exertion. After quantifying external load (i.e. running demand), several studies also found a high between-match variation (CV = 10.7 – 32.3%) in total high-speed running (i.e. ≥19.8 km/h) in European soccer players in high-level leagues (Bush et al., 2015; Carling, Bradley, McCall, et al., 2016; Gregson, Drust, Atkinson, & Salvo, 2010). Therefore, taking into account that ML varies significantly throughout the season, high-level soccer players should be prepared to respond to a high external (i.e. high-speed activity) and internal (i.e. dPE) load variability during the competition.

Moreover, the present study assessed for the first time ever both the dPE of professional soccer matches and its variability according to playing position. Interestingly, considerable differences were found between some playing positions, varying depending on the dimension of PE (Ekblom & Goldbarg, 1971; Hutchinson & Tenenbaum, 2006) assessed (i.e. PEres and PEmus) (Table 1). In other words, the differences between playing positions did not always arise between both dimensions of PE. These results suggest that, in addition to match playing time (Los Arcos et al., 2016), playing position also determines the demand of the different dimensions of PE.

In contrast to English Premier League players (Barrett et al., 2018), Spanish 2nd Division WBs did not have substantially higher PEres and PEmus than in the rest playing positions (Table 1). In general, the AvMs, WMs and WnBs reported the highest PEres and PEmus scores. Although more studies are necessary, players' competition level (English Premier League vs Spanish 2nd Division) and the differences among leagues depending on the country (England vs Spain) could explain the distinctions between both studies. Moreover, similarly to running demand at high speed (Bush et al., 2015; Carling, Bradley, Mccall, & Dupont, 2016; Gregson et al., 2010), match-to-match dPE variability was considerably different between playing positions (PEres, CV = 12.8 – 27.7%; PEmus, CV = 11.5 – 25.2%) (Table 1). However, this variability did not coincide with running demand variability. While the highest match-to-match variability measured by running demand (i.e. high-intensity running) was for central defenders in the English Premier League (CV = 20.8 – 32.3%) (Bush et al., 2015; Gregson et al., 2010) and for center half players (CV = 19.2–24%) in French Ligue 1 (Carling et al., 2016), the highest match-to-match dPE variability was for CMs (22.6 – 15.2% in PEres and PEmus) and for Ss (27.7 – 25.2% in PEres and PEmus). These differences between studies could be due to the use of the different methods (i.e. subjective and objective) to quantify ML, suggesting the simultaneous use of both tools (Silva et al., 2018), the competition level of the players (Bush et al., 2015), the country of the league and the tactical system (i.e. different playing positions) (Carling, McCall, Le Gall, & Dupont, 2015). Since match-to-match dPE and running demand at high-speed variability differ considerably between playing positions, soccer coaches should consider this when periodizing both pre- and post-match training sessions.

Previous studies in team sports (Los Arcos et al., 2016; Weston et al., 2015) found substantial differences between respiratory and muscular efforts in matches, suggesting a more sensitive evaluation of internal load during competitive team sport matches (Weston, 2013), which in turn could help to better inform individualized post-match recovery and training sessions (Weston et al., 2015). While Los Arcos et al. (2016) found unclear (ES = –0.17 ± 0.63; PEmus>PEres) differences between the two dimensions of PE for young professional soccer players who completed matches, taking together all players of the present study, Spanish 2nd Division players reported a higher PEmus than PEres ($p$ < 0.05; ES = 0.35, small). These results suggest that perceived muscular demand is greater than perceived respiratory effort for professional soccer players who complete the match. However, after carrying out a deeper analysis of the PEres–PEmus differences according to playing position, this varied (i.e. significant, substantial and sign). Specifically, higher values of PEmus than PEres were observed in CB, WM and CM positions (ES = from 0.46 to 0.68), while the WnB position reported greater PEres than PEmus ($p < 0.05$; ES = -0.35, small) (Table 2). Thus, soccer coaches should consider these differences when designing specific training programs in accordance to players' playing position.

In conclusion, soccer match exertion is different between some playing positions, but not always in both dimensions of PE (i.e. respiratory and muscular). Moreover, the study pointed out the fact that professional soccer players are exposed to a high match-to-match dPE variability that swings between playing positions. Thus, the deconstruction of the overall PE has revealed that different dimensions of PE are demanded in different ways and at different levels for some playing positions. These results confirm that the dPE improves the assessment of the soccer ML and can help pre- and post-match training sessions planning.

Even though this study has shown that match dPE and its variability differ considerably according to playing position in Spanish professional soccer players, we agree that, in future researches, other contextual factors (i.e. playing home or away games, score) should be considered to grasp a full understanding of how respiratory and muscular PE works in high level soccer players.

**References**

Anderson, L., Orme, P., Di Michele, R., Close, G. L., Milsom, J., Morgans, R., … Morton, P. (2016). Quantification of seasonal long physical load in soccer players with different starting status from the English Premier League: Implications for maintaining squad physical fitness. *International Journal of Sports Physilogy and Performance*, *11*(8), 1038–1046.

Arcos, A. L., Yanci, J., Mendiguchia, J., & Gorostiaga, E. M. (2014). Rating of muscular and respiratory perceived exertion in professional soccer players. *Journal of Strength and Conditioning Research*, *28*(11), 3280–3288.

Atkinson, G., & Nevill, A. (1998). Statistical methods for assssing measurement error (Reliability) in variables relevant to sports medicine. *Sports Medicine*, *26*(4), 217–238.

Azcárate, U., Yanci, J., & Arcos, A. L. (2018). Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players ' perceived training load. *Science and Medicine in Football*, *2*(1), 23–28.

Barrett, S., McLaren, S., Spears, I., Ward, P., & Weston, M. (2018). The influence of playing position and contextual factors on soccer players' match differential ratings of perceived exertion: A preliminary investigation. *Sports*, *6*(1), 13.

Bush, M. D., Archer, D. T., Hogg, R., & Bradley, P. S. (2015). Factors influencing physical and technical variability in the english premier league. *International Journal of Sports Physiology and Performance*, *10*(7), 865–872.

Carling, C., Bradley, P., 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.

Carling, C., McCall, A., Le Gall, F., & Dupont, G. (2015). What is the extent of exposure to periods of match congestion in professional soccer players? *Journal of Sports Science*, 33(20), 2116–24.

Castellano, J., Álvarez-Pastor, D., & Bradley, P. S. (2014). Evaluation of research using computerised tracking systems (Amisco and Prozone) to analyse physical performance in elite soccer: a systematic review. *Sports Medicine*, *44*(5), 701–712.

Clemente, F., Mendes, B., Nikolaidis, P. T., Calvete, F., Carriço, S., & Owen, A. L. (2017). Internal training load and its longitudinal relationship with seasonal player wellness in elite professional soccer. *Journal Physiology and Behavior*, *28*(179), 262–267.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. *(Second ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.*

Ekblom, B., & Goldbarg, A. N. (1971). The influence of physical training and other factors on the subjective rating of perceived exertion. *Acta Physiologica Scandinavica*, *83*(3), 399–406.

Fessi, M. S., & Moalla, W. (2018). Postmatch perceived exertion, feeling, and wellness in professional soccer players. *International Journal of Sports Physilogy and Performance*, *13*(5), 631–637.

Foster, C, Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115.

Gaudino, P., Iaia, F. M., Strudwick, A. J., Hawkins, R. D., Alberti, G., Atkinson, G., & Gregson, W. (2015). Factors influencing perception of effort (Session rating of perceived exertion) during elite soccer training. *International Journal of Sports Physiology and Performance*, *10*(7), 860–864.

Gregson, W., Drust, B., Atkinson, G., & Salvo, V. D. (2010). Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine*, *31*(4), 237–242.

Hutchinson, J. C. &, & Tenenbaum, G. (2006). Perceived effort: Can it be considered Gestalt? *Physiology of Sport and Exercise*, *7*(5), 463–476.

Los Arcos, A., Martínez-santos, R., Yanci, J., Mendiguchia, J., & Méndez-Villanueva, A. (2015). Negative associations between perceived training load , volume and changes in physical fitness in professional soccer players. *Journal of Sports Science and Medicine*, *14*(2), 394–401.

Los Arcos, A, Mendez-Villanueva, A., & Martínez-Santos, R. (2017). In-season training periodization of professional soccer players. *Biology of Sport*, *34*(2), 149–155.

Los Arcos, A., Mendez-Villanueva, A., Yanci, J., & Martinez-Santos, R. (2016). Respiratory and muscular perceived exertion during official games in professional soccer players. *International Journal of Sports Physiology and Performance*, *11*(3), 301–304.

Loturco, I., Nakamura, F. Y., Kobal, R., Gil, S., Pivetti, B., Pereira, L. A., & Roschel, H. (2016). Traditional periodization versus optimum training load applied to soccer players: Effects on neuromuscular abilities. *International Journal of Sports*

*Medicine*, *37*(13), 1051–1059.

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.

McLaren, S. J., Weston, M., Smith, A., Cramb, R., & Portas, M. D. (2015). Variability of physical performance and player match loads in professional rugby union. *Journal of Science and Medicine in Sport*, *19*(6), 493–497.

Sarmento, H., Clemente, F. M., Araújo, D., Davids, K., McRobert, A., & Figueiredo, A. (2018). What Performance Analysts Need to Know About ResearchTrends in Association Football (2012–2016): A Systematic Review. *Sports Medicine*, *48*(4), 799–836.

Sarmento, H., Marcelino, R., Anguera, M. T., CampaniÇo, J., Matos, N., & LeitÃo, J. C. (2014). Match analysis in football: a systematic review. *Journal of Sports Sciences*, *32*(20), 1831–1843.

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.

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. *Sports Medicine* (Vol. 48). Springer International Publishing.

Stevens, T. G. A., De Ruiter, C. J., Twisk, J. W. R., Geert, 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.

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2015). Monitoring fatigue during the in-season competitive phase in elite soccer players. *International Journal of Sports Physiology and Performance*, *10*(8), 958–964.

Weston, M. (2013). Difficulties in determining the dose-response nature of competitive soccer matches. *Journal of Athletic Enhancement*, *2*(1).

Weston, M., Siegler, J., Bahnert, A., McBrien, J., & Lovell, R. (2015). The application of differential ratings of perceived exertion to Australian Football League matches. *Journal of Science and Medicine in Sport*, *18*(6), 704–708.

Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *Journal of Sports Science*, *30*(15), 1573–1580.

Yanci, J., Martínez-Santos, R., & Los Arcos, A. (2014). Respiratory and muscular perceived efforts after official games in professional soccer players. *Journal of Strength and Conditioning Research*, *28*(11), 45–53.

# Subchapter 3.4. Paper 4

# Variability of professional soccer players' perceived match load after successive matches

Unai Azcárate, Asier Los Arcos & Javier Yanci

*International Journal of Sport Psychology*, (under review).

# Subchapter 3.4. Paper 4

## Variability of professional soccer players' perceived match load after successive matches

*Running title:* Variability soccer match perceived exertion

Unai Azcárate[1], Asier Los Arcos[1], Javier Yanci[1]
[1]*Physical Education and Sport Department, Faculty of Education and Sport, University of the Basque Country, UPV/EHU, Vitoria-Gasteiz, Spain.*

**Abstract**

This study analyzed the differential perceived ML accumulated by professional soccer players depending on their: (a) participation in several consecutive official matches within the same week (Pre_Cup, Cup, and Post_Cup), and (b) total match participation time (i.e. 90 min, 70-90 min and < 70 min). Participants were 21 Spanish Second Division professional soccer players (*M* age = 27.1, *SD* =3.3 years; *M* body height = 182.1, *SD* = 3.9 cm; *M* body mass = 75.8, *SD* = 5.14 kg). There were no significant differences ($p$<.05) in dRPE-ML among Pre_Cup, Cup and Post_Cup matches or in dRPE-ML between teams that took part in two or three official matches within the same week or three official matches in 2-4 consecutive weeks. The results suggest that participating in several matches in the same week does not increase accumulated PE for professional soccer players.

***Keywords**:* football; match; perceived exertion; differentiated sRPE.

## Introduction

In soccer, ML typically represents the highest TL of the week (Arcos et al., 2014; Los Arcos et al., 2017). For this reason, numerous research studies have analyzed and assessed ML in soccer by different methods (Carling et al., 2016; Kempton et al., 2015; Mohr et al., 2016; Rampinini et al., 2007). Some research which has analyzed the external ML (total distance, distance covered at different intensities, acceleration/decelerations, changes of direction, player load and peak metabolic power) using global positioning system (GPS) technology (Castagna et al., 2016; Draganidis et al., 2015; Kempton et al., 2015; Malone et al., 2015; Reilly et al., 2015), while other researchers have analysed internal ML through heart rate (HR) derived measurements such as Edward's ML and Stagno training impulses ($TRIMP_{MOD}$) (Campos-Vazquez et al., 2015; Jaspers et al., 2016) and through overall PE data (sRPE-ML) (Campos-Vazquez et al., 2015; Jaspers et al., 2016). In recent years, PE (sRPE) has increasingly been used to measure internal load in soccer matches (Los Arcos et al., 2016), due its simplicity, practicality, and low costs (Borg, 1982). As these measures have evolved, studies have found differential PE (dRPE) to be a valid method for assessing either TL or ML in soccer (Arcos et al., 2014; McLaren et al., 2017; Weston et al., 2015).

Professional soccer teams regularly participate in successive matches during a season; and, in most top leagues, it is normal for teams to compete in several different competitions such as National League and European Leagues for top-level teams (Mohr et al., 2016) or leagues and other official competitions (e.g., the King's Cup or other national competitions) during a long 9-11 month season. Some match-to-match variation has been observed in external ML (e.g., total high-speed running distance (THSR) *M* CV = 17.7, *SD* = 6.8%; high-speed running distance (HSR) *M* CV = 16.2, *SD* = 6.4% and total sprint distance (TSD) *M* CV = 30.8, *SD* = 11.2%) (Gregson et al., 2010). These variations in external ML throughout a season may be due to match contextual variables (i.e., match status, match location, opponent level, match half) (Bush et al., 2015; Rampinini et al., 2007; Varley et al., 2017), change in physical fitness of soccer players (Gregson et al., 2010), environmental conditions (Ekblom, 1986), playing style, tactical organization or team rotation (Carling et al., 2015). Several different researchers systematically analyzed in-season match-to-match variability for perceived ML and found contradictory results (Los Arcos et al., 2016, Arcos et al., 2014; Weston et al., 2015; Wrigley et al., 2012). Whereas overall sRPE match-to-match variability (i.e., quantified by means of the CV) in young soccer players was lower than 5% (Wrigley et al., 2012), a study with Australian soccer players found dRPE variability between matches over 129 consecutive matches (*M* =5.0, *SD* = 1.6 matches per player) during the AFL (Australian Football League) season to average 12.4% (*SD* = 1.5%) for perceived breathlessness (RPE-B), and 11.5% (*SD* =1.4%) for perceived leg exertion (RPE-L) (Weston et al., 2015). In young professional soccer players, for the Spanish 2nd B division championship that participated in two consecutive seasons (2011–12 and 2012–13) the perceived match-to-match variation averaged 10.2% (*SD* = 10.0%) for perceived respiratory exertion (sRPEres), and 18.1 (*SD* =12.0%) for perceived muscular exertion (sRPEmus) (Los Arcos et al., 2016). Although overall sRPE provides a valid global measure of intensity and load for capturing whole body exertion levels in the ML, it seems that scaling precision of the exertional signal is improved by differentiating perceptual reports according to their specific mediators (i.e., central respiratory [sRPEres] and local muscular [sRPEmus]), providing, in turn, the most important exertional signal of internal load (Los Arcos et al., 2016; Weston et al., 2015). Little research has analyzed differentiated perceived ML among professional soccer players (Los Arcos et al., 2016), suggesting value in analyzing the match-to-match PE variability over a lengthy season and determining whether there is variability in perceived ML between different types of competition.

The fact that the professional team must participate in several competitions at the same time leads to professional soccer players having to play up to three consecutive soccer matches within a week (Carling and Dupont, 2011; Mohr et al., 2016; Rampinini et al., 2007) and several training sessions with only 3–4 days of recovery between successive matches. This recovery time may be insufficient to restore initial homeostasis (Andersson et al., 2008; Mohr et al., 2016) and neuromuscular performance (Nedelec et al., 2014). The practical reality is that participating in multiple matches throughout the season may lead to a difficult post-match recovery and hinder structuring of post-match training strategies (Djaoui et al., 2016; Mohr et al., 2016). Since soccer match play places large physical demands (Mohr et al., 2016; Reilly et al., 2015) on soccer players, we must consider that the players' physical performance may be affected by a previous match. In previous research, reductions in players' external ML were observed among players required to participate in successive national competition matches with less than 72 hours between games (Odetoyinbo et al., 2007).

Similarly, Mohr et al. (2016) observed that elite male soccer players have a deficit in high-intensity running distance in matches 2 (7%, $p < 0.05$) and 3 (14%, $p < 0.05$), compared to match 1 of matches played in the same week. In contrast, external ML was unaffected in French Ligue 1 players who played three consecutive matches within seven days (Carling and Dupont, 2011). Other authors, such as Varley et al. (2017), also showed that under-23 soccer players who participated in successive matches were largely able to maintain their match running, though there were individual changes in match running over successive matches. Although the influence of participation in successive matches within same week has been analyzed through external load methods, to our knowledge, no study has yet analyzed ML through dRPE to see whether playing several consecutive soccer matches within the same week or even over several consecutive weeks could affect soccer players' perceived ML. Thus, this study aimed to assess the variability of the differentiated perceived ML (dRPE-ML) among professional team soccer players in Spanish league and CupM over a large competitive period (21 matches) by analyzing the development of dRPE-ML of players who took part in successive matches in the same week or in three matches per week over several consecutive weeks.

## Method

### *Participants*

A convenience sample of twenty-one professional soccer players (*M* = 27.1, *SD* = 3.3 years; *M* = 182.1, *SD* = 3.9 cm; M = 75.8, *SD* = 5.14 kg) from a single team in the Spanish Second Division League took part in this study. Among these players, one was a goalkeeper (28.0 years; 196.0 cm; 89.0 kg), four were center backs (*M* = 31.0, *SD* =1.4 years; *M* = 183.0, *SD* = 1.8 cm; *M* = 76.5, *SD* = 3.1 kg), seven were center midfielders (*M* = 27.2, *SD* = 2.5 years; *M* = 180.2, *SD* = 2.4 cm; *M* = 76.5, *SD* = 3.1 kg), five wide midfielders (*M* = 25.6, *SD* = 3.7 years; *M* = 180.2, *SD* = 1.3 cm; *M* = 73.1 ± 3.1 kg) and four forwards (M = 25.7, *SD* = 3.5 years; *M* = 182.7, *SD* = 3.1 cm; *M* = 74.2, *SD* = 7.2 kg). Summarizing data from 21 matches of the in-season period, of which 13 matches were played in Second Division National League (League) and eight matches were played in the Spanish National King's Cup (Cup) (Table 1), there were six "home" league matches and seven "away" league matches with four "home" CupM and four "away" CupM analyzed in this study. All the participants in this research trained 5-6 times (a.m. and/or p.m.) played per week. Due to technical staff decisions, there were also differences in the number of matches in which each player participated. Therefore, players participated in one, two or three matches (League and Cup) per week during the eight weeks of research assessment and this corresponded to the weeks in which the team disputed CupM. All participants were informed about the research procedures, requirements, benefits and risks prior to giving their written consent. This study was reviewed and approved by the local ethics committee and conducted in accordance with the Declaration of Helsinki (2013).

**Table 1.** Description of dates for 21 matches (Pre_Cup, Cup and Post_Cup) throughout the 8 weeks in-season period.

| *Week* | *Pre_Cup* | *Cup* | *Post_Cup* |
|---|---|---|---|
| **Wk_1** | September, 5th 2015 | September, 9th 2015 | September, 12nd 2015 |
| **Wk_2** | October, 10th 2015 | October, 14th 2015 | October, 17th 2015 |
| **Wk_3** | November, 29th 2015 | December, 3rd 2015 | December, 6th 2015 |
| **Wk_4** | December, 13rd 2015 | December, 16th 2015 | December, 20th 2015 |
| **Wk_5** | January, 3rd 2016 | January, 6th 2016 | January, 9th 2016 |
| **Wk_6** | January, 9th 2016 | January, 12nd 2016 | January, 17th 2016 |
| **Wk_7** | January, 17th 2016 | January, 21st 2016 | January, 24th 2016 |
| **Wk_8** | January, 24th 2016 | January, 28th 2016 | January, 31st 2016 |

Wk = week; Pre_Cup = match played before (same week) the King's Cup matches; Cup = King's Cup matches; Post_Cup = match played after (same week) the King's Cup matches.

## *Measures*

To quantify ML, we used the sRPE-ML method (Foster et al., 2001). Ten minutes after each official match (i.e., Pre_Cup, Cup and Post_Cup) (Los Arcos et al., 2016) we used Foster's 0–10 scale (Foster et al., 2001) to ask players to assess their PE in order to obtain their sRPE-ML. This question was asked by team fitness coach with regard to the player's respiratory and leg musculature effort so that a separate measurement for respiratory PE (sRPEres) and muscular PE (sRPEmus) could be obtained (Arcos et al., 2014; Los Arcos et al., 2015; Los Arcos et al., 2016; Weston et al., 2015). All players were familiarized with this method during the pre-season period (eight weeks in duration; July 9th - September 3rd) both in training (friendly) and official match sessions. Both respiratory and muscular perceived MLs (sRPEres-ML and sRPEmus-ML) were calculated, multiplying the sRPE value by the duration of participation time in each match (Los Arcos et al., 2016). The match duration was recorded, excluding warm-up and half-time rest periods (Los Arcos et al., 2016).

***Design and procedures***

Differentiated perceived ML data were collected over an 8-week in-season period during the 2015–16 season from the first week of September (i.e., third week of official matches) to the last week of January (i.e., thirty-first match between League and Cup) in the first half-season. Given that the team participated in eight King's Cup matches, all matches (n = 21) were classified into three types: (a) those played before (in the same week) King's Cup matches (Pre_Cup, n = 8); (b) King's Cup matches (Cup, n = 8); and (c) those played after (in the same week) King's Cup matches (Post_Cup, n = 8). At the same time, participation time in a match was considered (i.e., 90 min., 70–90 min. and < 70 min.) (Los Arcos et al., 2016) for each player. To obtain the team's general dRPE, all of each player's data was considered (regardless of whether they played for 90 min., 70–90 min. and/or < 70 min.). Furthermore, concerning the analysis of players' different dRPEs, data from those players who took part in two matches (Pre_Cup and Cup or Cup and Post_Cup) or three matches (Pre_Cup, Cup and Post_Cup) in the same week and who participated for the same amount of time (i.e., 90 min., 70–90 min. and < 70 min.) in each one of them (i.e., different participation type from Pre_Cup, Cup and/or Post_Cup) were included in the analysis. Moreover, individual dRPE data for professional soccer players who played three matches per week over 2, 3 or 4 consecutive weeks were analyzed. Only the players who were available to compete for a whole week with the team and also train during the week were considered.

***Statistical Analyses***

Raw data are presented as mean and standard deviation (SD). Intermatch variation throughout the assessment period (n = 21 matches) and between groups Pre_Cup, Cup and Post_Cup was quantified by means of the coefficient of variation (CV) (Atkinson and Nevill, 1998). We employed a repeated measure ANOVA with Bonferroni post hoc test to determine perceived dRPE (sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) group mean differences between matches (comparing 21 matches or Pre_Cup, Cup or Post_Cup matches). In the case of dRPE among the players who participated in two matches during the same week (Pre_Cup and Cup or Cup and Post_Cup), group differences were calculated using a student paired *t*-test. Furthermore, differences in the dRPE were assessed by calculating the Cohen's effect size (Cohen, 1988). Effect sizes (ES) between < 0.2, 0.2 – 0.6, 0.6 – 1.2, 1.2 – 2.0, and 2.0 – 4.0 were considered as trivial, small, moderate, large and very large, respectively (Hopkins et al., 2009). Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile difference or change (0.2 multiplied by the between subject SD, based on Cohen's effect size principle). Quantitative chances of higher or lower differences were evaluated qualitatively as follows: < 1%, almost certainly not; 1 − 5%, very unlikely; 5 − 25%, unlikely; 25 − 75%, possible; 75 − 95%, likely; 95 − 99%, very likely; > 99%, almost certain. If the chance of having greater or lower values compared to the smallest worthwhile differences was > 5%, the true difference was assessed as unclear. The relationship between matches of Pre_Cup, Cup and Post_Cup for the dRPE of professional soccer players who participated in two or three consecutive matches and who participated in a similar time length (i.e., 90 min., 70–90 min. and < 70 min.) were determined using Pearson's correlation analysis (*r*). The following criteria were adopted for interpreting the magnitude of correlations between dRPE variables: ≤ 0.1 trivial, > 0.1 – 0.3 small, > 0.3 – 0.5 moderate, > 0.5 – 0.7 large, > 0.7 – 0.9 very large, and > 0.9 – 1.0 almost perfect (Hopkins et al., 2009). Inference about the true (large-sample) value of a correlation was based on uncertainty regarding its magnitude (Batterham and Hopkins, 2006): if the 90% confidence limits (CL) overlapped small positive and negative values, the magnitude was deemed unclear; otherwise, the magnitude was deemed to be the observed magnitude. The data analysis was presented using a modified statistical Excel spreadsheet (Hopkins, 2007; Hopkins, 2006) and with the Statistical Package for Social Sciences (version 23.0 for Windows, SPSS® Inc, Chicago, IL, USA). Statistical significance was set at $p < 0.05$.

## Results

### *Perceived match load (ML) for team in the League and Cup official matches*

Considering the perceived ML of the team (i.e., all players who played the matches) in all the official matches (n = 21), there were no significant differences ($p > 0.05$) between matches for sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML values (Figure 1). The coefficient of variation (CV) between all matches was 6.9%, 7.8%, 11.8% and 12.3% for sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML, respectively.

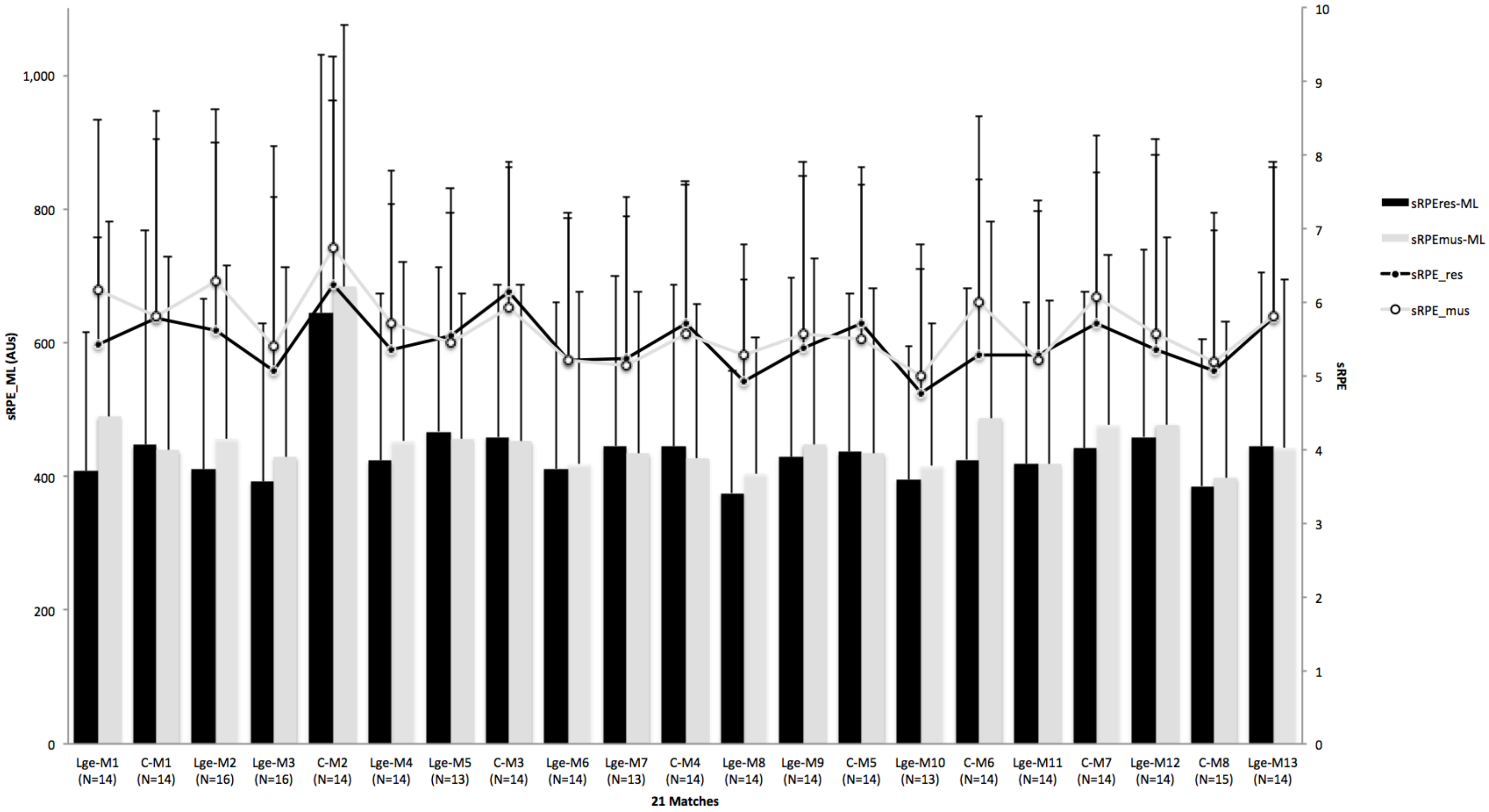


**Figure 1.** Team mean (± standard deviation) perceived match load (sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML), throughout a period of 21 matches (League, n = 13 matches, Cup, n = 8 matches).

C = King's Cup matches; Lge = match played in Spanish Second Division League; AUs = arbitrary units; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPEmus-ML = muscular session-rating of perceived exertion match load.

Thus, there were no significant differences between all Pre_Cup matches (n = 8, 111 occurrences), all Cup matches (n = 8, 113 occurrences) and all Post_Cup matches (n = 8, 113 occurrences) ($p > 0.05$, ES = -0.04 – 0.21, unclear or possibly small) for the team's perceived ML (Figure 2). The coefficient of variation (CV) between Pre_Cup, Cup, and Post_Cup matches was 4.5%, 3.8%, 5.2% and 4.4% to sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML, respectively.

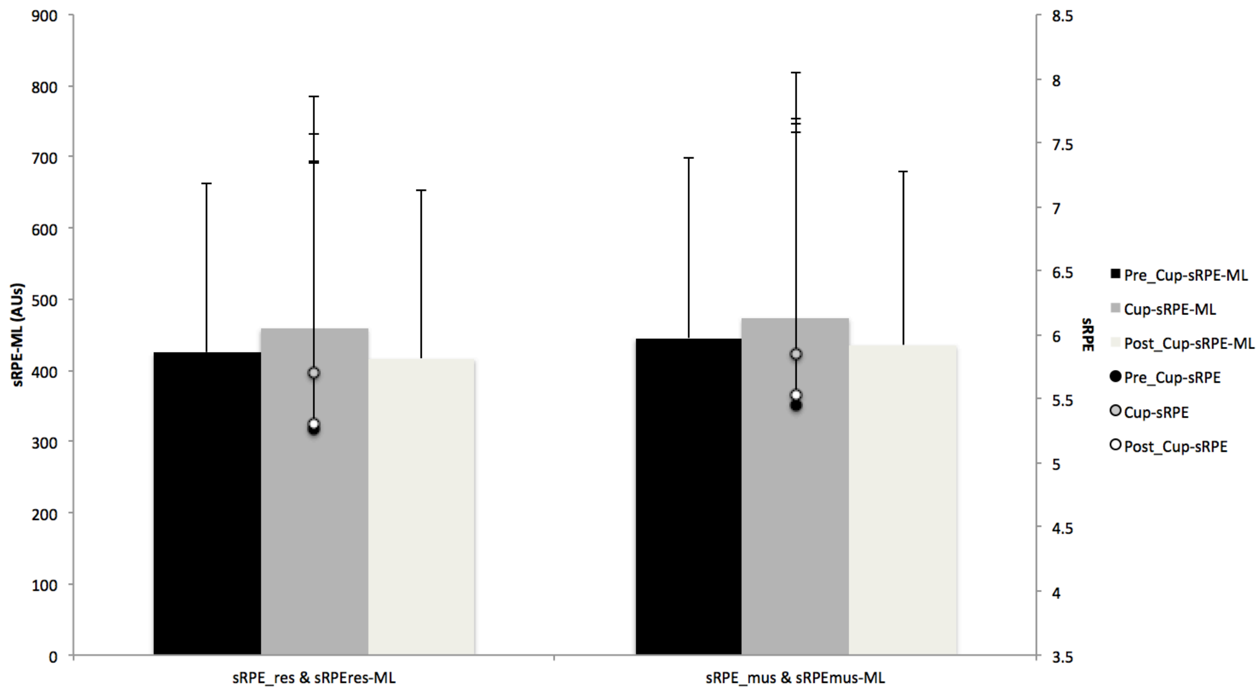


**Figure 2.** Perceived match load for team (sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) for Pre_Cup, Cup and Post_Cup matches.
AUs = arbitrary units; Pre_Cup = match played before (in the same week) the King's Cup matches; Cup = King's Cup matches; Post_Cup = match played after (in the same week) the King's Cup matches; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPEmus-ML = muscular session-rating of perceived exertion match load.

### *Comparison of perceived TL among the professional soccer players who participated in 2 consecutive matches (Pre_Cup and Cup or Cup and Post_Cup) throughout same week*

The comparison of the results for sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML among soccer players who participated in two consecutive matches throughout same week (Pre_Cup and Cup, n = 12 professional soccer players, 26 occurrences, or Cup and Post_Cup, n = 12 professional soccer players, 25 occurrences) when both participated for a similar time length (i.e., 90 min., 70–90 min. and < 70 min.) are presented in Figure 3. There were no significant differences between Pre_Cup and Cup matches (*p* > 0.05, ES = -0.06 – 0.11, unclear) (Figure 3A) or between Cup and Post_Cup matches (*p* > 0.05, ES = 0.02 – 0.12, unclear) (Figure 3B) on any perceived effort variable (i.e., sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML). Coefficient of variation (CV) to Pre_Cup and Cup matches was 1.9%, 1.6%, 2.3% and 4.6% and between Cup and Post_Cup matches was 4.4%, 3.9%, 1.9% and 1.1% to sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML, respectively.

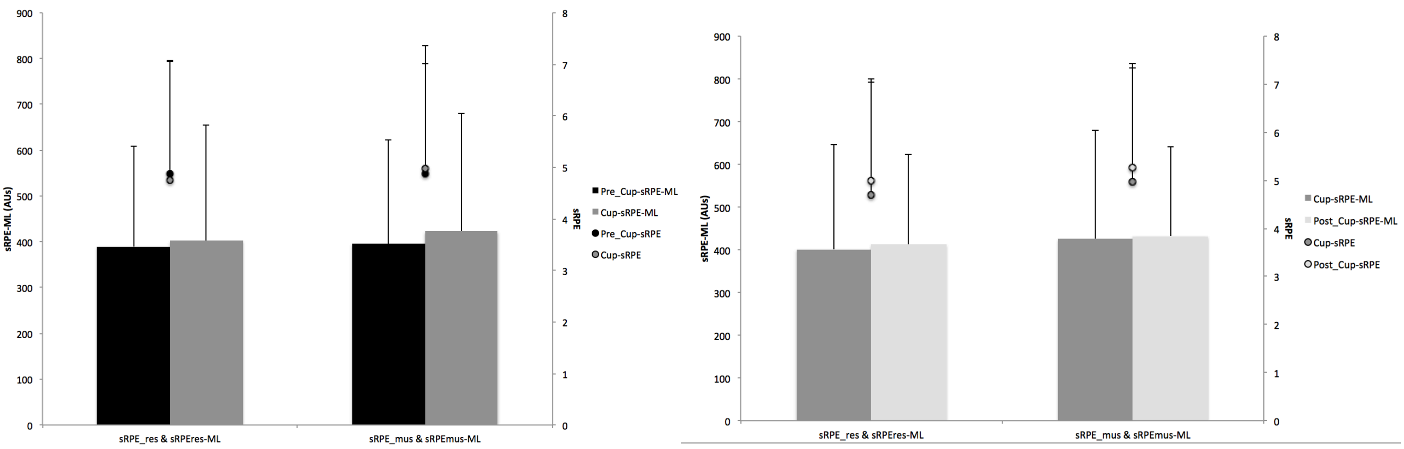


**Figure 3.** Results to dRPE match load (i.e. sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) for professional soccer players that participated in 2 consecutive matches of same week as Pre_Cup and Cup (3A) and as Cup and Post_Cup (3B) and considering participated in a similar groups of minutes for the matches (i.e. 90 min, 70-90 min and < 70 min).
AUs = arbitrary units; Pre_Cup = match played before the King's Cup matches; Cup = King's Cup matches; Post_Cup = match played after the King's Cup matches; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPEmus-TL = muscular session-rating of perceived exertion match load.

The correlations between Pre_Cup vs. Cup or Cup vs. Post_Cup for PE variables (i.e. sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) for professional soccer players that participated in two consecutive matches throughout the week are shown in Table 2.

**Table 2.** Correlation values (r, ±90% CL) for dRPE variables (i.e. sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) between Pre_Cup vs. Cup and Cup vs. Post_Cup for professional soccer players who played two consecutive matches the same week.

| | ***Pre_Cup vs. Cup (n = 12 players, 26 occurrences)*** | ***Cup vs. Post_Cup (n = 12 players, 25 occurrences)*** |
|---|---|---|
| **sRPE_res** | 0.82;±0.12** Very large<br>100/0/0, Most likely | 0.63;±0.21** Large<br>100/00/0, Most likely |
| **sRPE_mus** | 0.80;±0.13** Very large<br>100/0/0, Most likely | 0.47;±0.27* Moderate<br>97/3/0, Very likely |
| **sRPEres-ML (AUs)** | 0.86;±0.09** Very large<br>100/0/0, Most likely | 0.56;±0.24** Large<br>99/1/0, Very likely |
| **sRPEmus-ML (AUs)** | 0.76;±0.15 ** Very large<br>100/0/0, Most likely | 0.47;±0.27* Moderate<br>97/3/0, Very likely |

Pre_Cup = match played before the King's Cup matches; Cup = King's Cup matches; Post_Cup = match played after the King's Cup matches; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEmus-ML = muscular session-rating of perceived exertion match load; AUs = arbitrary units; CL = confidence limits; Significant correlation (*p < 0.05, **p < 0.01).

### *Comparison of perceived exertion match load among the professional soccer players that disputed 3 consecutive matches during the same week*

Comparisons of sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML in soccer players that participated in three consecutive matches during the same week (Pre_Cup, Cup and Post_Cup, n = 9 professional soccer players, 21 occurrences) when both participated for similar time lengths (i.e. 90 min, 70-90 min and < 70 min) are presented in Figure 4. There were no significant differences ($p > 0.05$, ES = -0.10 to 0.26, unclear to possibly small) between PE ML for soccer players who participated in three consecutive matches the same week (Pre_Cup, Cup and Post_Cup). Coefficient of variation (CV) between Pre_Cup, Cup, and Post_Cup matches was 5.0%, 6.1%, 5.7% and 7.0% for sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML, respectively.

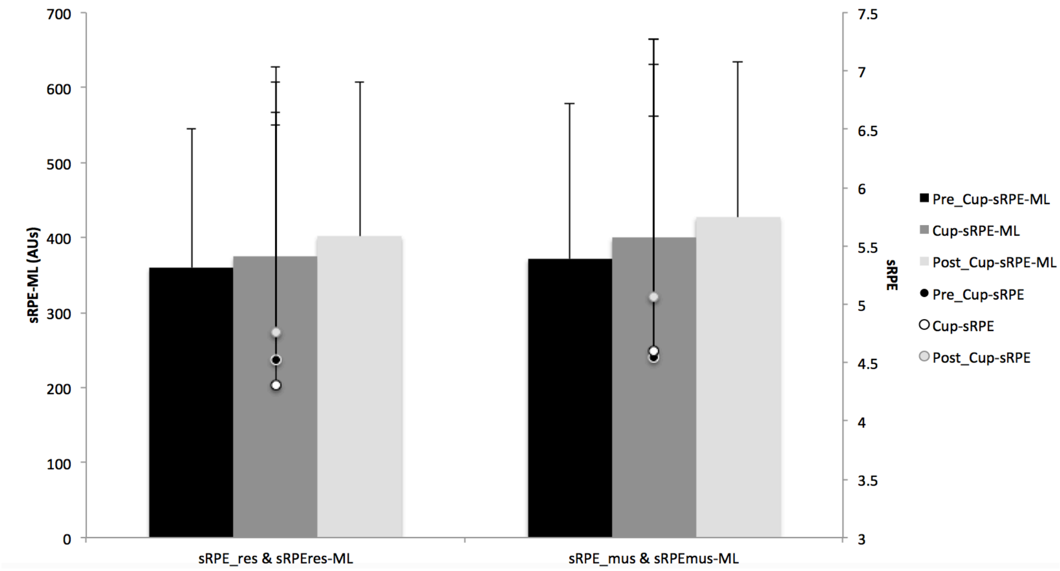


**Figure 4.** Results for sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML in soccer players that participated in 3 consecutive matches of the same week (Pre_Cup, Cup and Post_Cup, n = 9 professional soccer players, 21 occurrences) when both participated in a similar group of minutes for the matches (i.e. 90 min, 70-90 min and < 70 min).
AUs = arbitrary units; Pre_Cup = match played before the King's Cup matches; Cup = King's Cup matches; Post_Cup = match played after the King's Cup matches; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPEmus-ML = muscular session-rating of perceived exertion match load.

The correlations obtained between matches of Pre_Cup vs. Cup, Cup vs. Post_Cup and Pre_Cup vs. Post_Cup for professional soccer players who participated in three consecutive matches throughout the week and for a similar time length (i.e., 90 min., 70–90 min. and < 70 min.) on PE variables (i.e., sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) are shown in Table 3.

**Table 3**. Correlation values (r, ±90% CL) for dRPE variables (i.e. sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) between Pre_Cup vs. Cup, Cup vs. Post_Cup and Pre_Cup vs. Post_Cup for professional soccer players who played 3 consecutive matches (n = 9 professional soccer players, 21 occurrences) the same week and a similar number of minutes (i.e. 90 min, 70-90 min and < 70 min).

| | ***Pre_Cup vs. Cup*** | ***Cup vs. Post_Cup*** | ***Pre_Cup vs. Post_Cup*** |
|---|---|---|---|
| **sRPE_res** | 0.82;±0.13** Very large 100/0/0, Most likely | 0.62;±0.24** Large 100/0/0 Most likely | 0.70;±0.20** Very large 100/0/0, Most likely |
| **sRPE_mus** | 0.80;±0.15** Very large 100/0/0, Most likely | 0.45;±0.30* Moderate 95/4/1 Likely | 0.61;±0.24** Large 99/1/0, Most likely |
| **sRPEres-ML (AUs)** | 0.87;±0.10** Very large 100/0/0, Most likely | 0.56;±0.26** Large 99/1/0 Very likely | 0.77;±0.16** Very large 100/0/0. Most likely |
| **sRPEmus-ML (AUs)** | 0.73;±0.19** Very large 100/0/0, Most likely | 0.48;±0.29* Moderate 96/3/1 Very likely | 0.69;±0.21** Large 100/0/0, Most likely |

Pre_Cup = match played before the King's Cup matches; Cup = King's Cup matches; Post_Cup = match played after the King's Cup matches; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPEmus-ML = muscular session-rating of perceived exertion match load; AUs = arbitrary units; CL = confidence limits; Significant correlation (*p < 0.05, **p < 0.01).

***Comparison of perceived exertion match load among the professional soccer players who disputed 3 consecutive matches during the 2, 3 or 4 consecutive weeks***

Individual results for dRPE (sRPE_res, sRPE_mus, sRPEres-ML and sRPEmus-ML) for professional soccer players who participated for 2–4 consecutive weeks in both official League and King's Cup and for a similar time length (i.e., 90 min., 70–90 min. and < 70 min.) are shown in Table 4. Two players alone (center backs) disputed three matches in the same week throughout two consecutive weeks, and a single player (goalkeeper) disputed three matches throughout four consecutive weeks for a similar time length (i.e., 90 min., 70–90 min. and < 70 min.).

**Table 4.** Individual dRPE match load results (percentage difference from the previous match) for professional soccer players that participated in several consecutive weeks (i.e. from 2 to 4 weeks) according to a similar number of minutes played (i.e. 90 min).

| | | ***Min*** | ***Match dates*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ***29 Nov*** | ***3 Dec*** | ***6 Dec*** | ***13 Dec*** | ***16 Dec*** | ***20 Dec*** | | | |
| Player 1 CB | **sRPE_res** | 90 min | 7 | 7 (0%) | 8 (14.29%) | 7 (12.50%) | 8 (14.29%) | 6 (25%) | | | |
| | **sRPE_mus** | | 6 | 7 (16.67%) | 8 (14.29%) | 6 (-25%) | 7 (16.67%) | 7 (0%) | | | |
| | **sRPEres-ML** | | 658 | 651 (-1.06%) | 744 (14.29%) | 651 (-12.50) | 744 (14.29%) | 558 (-25%) | | | |
| | **sRPEmus-ML** | | 564 | 651 (15.43%) | 744 (14.29%) | 558 (-25%) | 651 (16.67%) | 651 (0%) | | | |
| Player 2 CB | **sRPE_res** | 90 min | 5 | 5 (0%) | 5 (0%) | 6 (20%) | 7 (16.67%) | 5 (-28.57%) | | | |
| | **sRPE_mus** | | 5 | 6 (20%) | 6 (0%) | 6 (0%) | 7 (16.67%) | 5 (-28.57%) | | | |
| | **sRPEres-ML** | | 470 | 465 (1.06%) | 465 (0%) | 558 (20%) | 651 (16.67%) | 465 (-28.57%) | | | |
| | **sRPEmus-ML** | | 470 | 558 (18.72%) | 558 (0%) | 558 (0%) | 651 (16.67%) | 465 (-28.57%) | | | |
| | | | ***3 Jan*** | ***6 Jan*** | ***9 Jan*** | ***12 Jan*** | ***17 Jan*** | ***21 Jan*** | ***24 Jan*** | ***28 Jan*** | ***31 Jan*** |
| Player 3 GK | **sRPE_res** | 90 min | 3 | 2 (-33.33%) | 2 (0%) | 2 (0%) | 3 (50%) | 4 (33.33%) | 3 (-25%) | 3 (0%) | 2 (-33.33%) |
| | **sRPE_mus** | | 3 | 3 (0%) | 3 (0%) | 2 (-33.33%) | 3 (50%) | 4 (33.33%) | 3 (-25%) | 3 (0%) | 2 (-33.33%) |
| | **sRPEres-ML** | | 279 | 186 (-33.33%) | 186 (0%) | 186 (0%) | 279 (50%) | 372 (33.33%) | 279 (-25%) | 276 (-1.08%) | 186 (32.61%) |
| | **sRPEmus-ML** | | 279 | 279 (0%) | 279 (0%) | 186 (-33.33%) | 279 (50%) | 372 (33.33%) | 279 (-25%) | 276 (-1.08%) | 186 (32.61%) |

CB = central back; GK = goalkeeper; sRPE_res = respiratory session-rating of perceived exertion; sRPE_mus = muscular session-rating of perceived exertion; sRPEres-ML = respiratory session-rating of perceived exertion match load; sRPEmus-ML = muscular session-rating of perceived exertion match load.

**Discussion**

The aims of this study were to assess the variability of the dRPE-ML of Spanish Second Division soccer players in 21 League and King's Cup official matches throughout the in-season period, and to analyze the development of dRPE-ML in professional soccer players who participated in successive soccer matches within the same week (Pre_Cup and Cup, Cup and Post_Cup or Pre_Cup, Cup and Post_Cup) or who played three matches per week over several consecutive weeks, while classifying professional soccer players into groups depending on their total participation time during the matches disputed (i.e., 90 min., 70–90 min. and < 70 min.). To our knowledge, this is the first soccer study in which the dRPE-ML obtained over a period of two or three official matches within the same week was analyzed. Our main findings reflected: (a) no differences in team dRPE-ML between Pre_Cup, Cup and Post_Cup matches, and (b) no dRPE-ML differences for players who took part in two or three official matches within the same week or three official matches in 2–4 consecutive weeks with similar lengths of participation in all of them, i.e., 90 min., 70–90 min. and < 70 min.).

The current study described the dRPE-ML throughout an in-season period of consecutive weeks (i.e., eight weeks, 21 matches), and our data revealed similar team dRPE-ML accumulated in official matches (n = 21) across Pre_Cup matches (n = 8, 111 occurrences), all Cup matches (n = 8, 113 occurrences) and all Post_Cup matches (n = 8, 113 occurrences) ($p > 0.05$, CV = 1.1 – 12.3%). Weston et al. (2015), provided a threshold (of ~10%) before interpreting likely change to of between-match differences in all dimensions of dRPE (i.e., legs (RPE-L); breathlessness (RPE-B); match physical exertion (RPE-M) and match technical demand (RPE-T)), since dRPE scores were variable between 129 Australian Football League (AFL) matches. Other authors (e.g., Kempton et al., 2015) showed greater intermatch variability to high-speed activities and technical performance measures (CV = 13.2 – 28.6%) in comparison to our study. Similarly, Gregson et al. (2010) assessed short-term (i.e., 8-week period) between-match variability demonstrating high CVs (~16 – 30%) in high-speed activity; and recently, Bush et al. (2015) found, in matches disputed across multiple seasons (2005–2006 to 2012–2013) CVs for high-intensity running distance ranging from 14 - 20% of variability in specific actions of the game. Previously, other researchers (Rampinini, Coutts, et al., 2007) showed slightly less match-to-match variation in match distance covered at different intensities (i.e., total distance (TD), CV = 2.4%; high-intensity running (HIR), CV = 6.8%; and very high-intensity running (VHIR), CV = 14.4%) among professional soccer players, using the semi-automated, computerized match-analysis system. Rampinini et al. (2007) showed that players obtained higher TD and completed more HIR when playing against higher-quality opponents (i.e., the best national and international teams) in comparison to lower-quality opponents. Nonetheless, in our research, although the team we studied played against other teams of different competitive levels (i.e., different ranking though part of the same league or/and a different category in CupM) their dRPE-ML was not significantly different in these observed matches. Possibly, the contradictory results among these studies may be due to either (a) the influence of different competitive categories of these matches for the different teams studied (i.e., six UEFA European Champions League, three National Cup matches and 25 National League vs. eight National Cup matches and 13 Second Division League) or (b) differences with regard to the opponent teams with respect to factors such as playing styles, fitness characteristics and tactics. Furthermore, the different instrument for assessing the ML between matches (i.e. semi-automatic video match-analysis image recognition system vs. RPE or dRPE) may have affected the results of the two studies.

Besides knowing the team ML among different matches, it would also be interesting to analyze dRPE-ML in players who participated in the two pairs of match types (Pre_Cup and Cup or Cup and Post_Cup) or the three matches (Pre_Cup, Cup and Post_Cup) during the same week throughout several consecutive weeks. In our research, the first effort to study the ML effects of playing in closely scheduled matches, we found that playing two or three matches throughout the same week did not affect the dRPE-ML of professional Spanish soccer players. Players who disputed three matches during the same week over several consecutive weeks (from 2 – 4 weeks) did not show the expected progressive increase in dRPE-ML with respect to previous matches. Our results are in line with those obtained by Carling and Dupont (2011), who did not point out any relevant differences in match running performance for soccer players who participated in three successive matches over seven days. In the same way, Varley et al. (2017) also observed that soccer players could largely maintain their match running performance in three successive matches within seven days. Nevertheless, our results partially resemble findings of Mohr et al. (2016) who discovered (a) no difference in total distance, sprinting distance, peak sprinting speed, and number of accelerations and decelerations between three simulated soccer games played in one week; but also (b) significant match-to-match variations between 1 – 2 and 2 – 3 matches in high-intensity actions but not between 1–3 matches. Interestingly, these authors found differences (CV = 6 and 7%; $p < 0.05$) in the impacts (i.e., jumps) that occurred between 1 – 3 and 2 – 3 matches but not between 1 – 2 matches. In this sense, these authors showed that players who participated in three consecutive matches in the same week obtained higher creatine kinase (CK) and delayed onset muscle soreness (DOMS) values than players who participated in a single match per week. While it first seems that muscular biomarkers or physiological responses might increase by participating in several consecutive soccer matches in the same week, soccer players appear to be able to maintain external ML (physical fitness responses) (Mohr et al., 2016) and internal match load (dRPE-ML), despite closely scheduled match play.

Our failure to find any higher dRPE-ML for players who participated in two or three consecutive matches in the same week or three matches in the same week over several consecutive weeks (from 2 – 4 weeks) may have been due to these players' post-match recovery strategies. Previous studies (Andersson et al., 2008; Draganidis et al., 2015; Mohr et al., 2016) that quantified post-match recovery observed that after a 72 hour post-match time span, competitive male soccer players' physical performance recovered. Andersson et al. (2008) and Draganidis et al. (2015) showed that in the first 12 hours after participating in a soccer match the maximal performance first declines on a downward slope, and 48 hours later shows an upward recovery slope. Similar results were obtained during the first 24 hours after a soccer match (Nedelec et al., 2014). In our study, the elapsed time between the analyzed matches was always 72 hours or longer (Table 1), possibly time enough to recover from the effort expended during the previous match (Andersson et al., 2008; Draganidis et al., 2015; Mohr et al., 2016; Nedelec et al., 2014). Thus, an adequate recovery between matches might have explained our failure to observe an upper dRPE-ML when players competed in consecutive matches in the same week. While more research is needed to confirm this possible explanation, performing specific training to improve post-match recovery of professional soccer players could be important, especially for professional soccer players who participate in several consecutive matches throughout the same week and during several consecutive weeks (from 2 – 4 weeks).

## Conclusion

In conclusion, the present study showed that match internal load assessed through dRPE-ML barely varies throughout long periods of time (21 league and cup official matches disputed in an 8-week in-season period). The fact that the dRPE-ML does not change significantly from closely scheduled matches may be due to our having allowed a post-match recovery of at least 72 hours. The Authors declare that there is no conflict of interest.

**References**

Andersson, H., Ekblom, B., & Krustrup P. (2008). Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *Journal of Sports Science,* 26, 113–122.

Arcos, A., Yanci, J., Mendiguchia, J., & Gorostiaga, E. (2014) Rating of muscular and respiratory perceived exertion in professional soccer players. *Journal of Strength and Conditioning Research,* 28, 3280–3288.

Atkinson, G., & Nevill, A. (1998). Statistical methods for assssing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine,* 26, 217–238.

Batterham, A. M., & Hopkins W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance sport,* 1, 50–57.

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise, 14*, 377–381.

Bush, M. D., Archer, D. T., Hogg, R., & Bradley, P. S. (2015). Factors influencing physical and technical variability in the english premier league. *International Journal of Sports Physiology and Performance,* 10, 865–872.

Campos-Vazquez, M. A., Mendez-Villanueva, A., Gonzalez-Jurado, J. A., León-Prados, J. A., Santalla, A., & Suarez-Arrones, L. (2015). Relationships between RPE- and HR-derived measures of internal training load in professional soccer players: a comparison of on-field integrated training sessions. *International Journal of Sports Physiology and Performance,* 10, 587–592.

Carling, C., Bradley, P., Mccall, A., & Dupont, G. (2016). Match-to-match variability in high-speed running activity in a professional soccer team. *Journal of Sports Science,* 34, 2215–2223.

Carling, C., & Dupont, G. (2011). Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play?. *Journal of Sports Science,* 29, 63–71.

Carling, C., McCall, A., Le Gall, F., & Dupont, G. (2015). What is the extent of exposure to periods of match congestion in professional soccer players?. *Journal of Sports Science,* 33, 2116–24.

Castagna, C., Varley, M., Póvoas, S. C., & D'Ottavio, S. (2016). The evaluation of the match external load in soccer: methods comparison. *International Journal of Sports Physiology and Performance,* 6, 1–25.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, New Jork: Lawrence Erlbaum Associates, (Second ed).

Djaoui, L., Diaz-Cidoncha, J., Hautier, C., & Dellal, A. (2016). Kinetic post-match fatigue in professional and youth soccer players during the competitive period. *Asian Journal of Sports Medicine,* 7, 1–7.

Draganidis, D., Chatzinikolaou, A., Avloniti, A., Barbero-Álvarez, J. C., Mohr, M., Malliou, P., Gourgoulis, V., Deli, C. K., Douroudos, I. I., Margonis, K., Gioftsidou, A., Flouris, A.D., Jamurtas, A. Z., Koutedakis, Y., & Fatouros, I. G. (2015). Recovery kinetics of knee flexor and extensor strength after a football match. *PLoS One,* 10, e0133459.

Ekblom, B. (1986). Applied physiology of soccer. *Journal of Sports Medicine,* 3, 50–60.

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research,* 15, 109–15.

Gregson, W., Drust, B., Atkinson, G., & Salvo V. D. (2010). Match-to-match variability of high-speed activities in premier league soccer. *International Journal of Sports Medicine,* 31, 237–242.

Hopkins, W. G. (2006). Spreadsheets for analysis of controlled trials with adjustment for a predictor. *Sportscience,* 10, 46–50.

Hopkins, W. G. (2007). A spreadhseet to compare means of two groups. *Sportscience,* 11, 22–23.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise,* 41, 3–12.

Jaspers, A., Brink, M. S., Probst, S. G., Frencken, W. G., & Helsen, W. F. (2017). Relationships between training load indicators and training outcomes in professional soccer. *Sports Medicine,* 47, 533–544.

Kempton, T., Sullivan, C., Bilsborough, J. C., Cordy, J., & Coutts, A. J. (2015). Match-to-match variation in physical activity and technical skill measures in professional Australian Football. *Journal of Science and Medicine in Sport,* 18, 109–113.

Los Arcos, A., Martínez-Santos, R., Yanci, J., Mendiguchia, J., & Mendez-Villanueva, A. (2015). Negative associations between perceived training load, volume and changes in physical fitness in professional soccer players. *Journal of Sports Science* *and Medicine,* 14, 394–401.

Los Arcos, A., Mendez-Villanueva, A., & Martínez-Santos, R. (2017). In-season training periodization of professional soccer players. *Biology of Sport,* 34, 149–155.

Los Arcos, A., Mendez-Villanueva, A., Yanci, J., & Martinez-Santos, R. (2016). Respiratory and muscular perceived exertion during official games in professional soccer players. *International Journal of Sports Physiology and Performance,* 11, 301–4.

Malone, J. J., Di Michele, R., Morgans, R., Burgess, D., Morton, J. P., & Drust, B. (2015). Seasonal training-load quantification in elite English premier league soccer players. *International Journal of Sports Physiology and Performance,* 10, 489–497.

McLaren, S., Smith, A., Spears, I., & Weston, M. (2017). A detailed quantification of differential ratings of perceived exertion during team-sport training. *Journal of Science and Medicine in Sport,* 20, 290–295.

Mohr, M., Draganidis, D., Chatzinikolaou, A., Barbero-Álvarez, J. C., Castagna, C., Douroudos, I., Avloniti, A., Margeli, A., Papassotiriou, I., Flouris, A. D., Jamurtas, A. Z., Krustrup, P., & Fatouros, I. G. (2016). Muscle damage, inflammatory, immune and performance responses to three football games in 1 week in competitive male players. *European Journal of Applied Physiology,* 116, 179–193.

Nedelec, M., McCall, A., Carling, C., Legall, F., Berthoin, S., & Dupont, G. (2014). The influence of soccer playing actions on the recovery kinetics after a soccer match. *Journal of Strength and Conditioning Research,* 28, 1517–1523.

Odetoyinbo, K., Wooster, B., & Lane, A. (2007). *The effect of a succession of matches on the activity profiles of professional soccer players*. UK: Routledge, (Eds).

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2007). Variation in top level soccer match performance. *International Journal of Sports Medicine,* 28, 1018–1024.

Reilly, B., Akubat, I., Lyons, M., & Collins, D. K. (2015). Match-play demands of elite youth Gaelic football using global positioning system tracking. *Journal of Strength and Conditioning Research,* 29, 989–996.

Varley, M. C., Di Salvo, V., Modonutti, M., Gregson, W., & Mendez-Villanueva, A. (2018). The influence of successive matches on match-running performance during an under-23 international soccer tournament: The necessity of individual analysis. *Journal of Sports Science,* 36, 585–591.

Weston, M., Siegler, J., Bahnert, A., McBrien, J., & Lovell, R. (2015). The application of differential ratings of perceived exertion to Australian Football League matches. *Journal of Science and Medicine in Sport,* 18, 704–708.

Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *Journal of Sports Science,* 30, 1573–1580.

# Chapter 4

## Conclusions

# CHAPTER 4. CONCLUSIONS

The thesis conclusions were the following:

- Previous match participation had a substantial effect on players' accumulated weekly TLs, with greater match participation associated with higher weekly loads regardless of compensatory training strategies. On the other hand, the length of the between-match microcycle during 1-match weeks had no effect on players' accumulated weekly workloads.

- The higher RPEmus than RPEres both in TL and ML suggest that training sessions and soccer matches produce a large involvement to neuromuscular performance. Furthermore, a 5–8 week period showed higher dRPE TL values than a 1–4 week period. Further research is needed to find out whether these differences are due to players' higher levels of fatigue or to a change in the training sessions performed. Conversely, positive and large significant associations between cardiovascular capacity in RPEmus ML, along with negative and large significant associations between cardiovascular capacity in RPEres TL values, were obtained. This fact leads us to infer that better cardiovascular capacity could be linked with a lower RPEres TL and higher RPEmus ML.

- Soccer match exertion is different between some playing positions, but not always in both dimensions of PE (i.e. respiratory and muscular). Moreover, professional soccer players are exposed to a high match-to-match dPE variability that swings between playing positions. Thus, the deconstruction of the overall PE has revealed that different dimensions of PE are demanded in different ways and at different levels for some playing positions. These results confirm that the dPE improves the assessment of the soccer ML and can help pre- and post-match training sessions planning.

- The match dPE and its variability differ considerably according to playing position in Spanish professional soccer players, therefore in future researches, other contextual factors (i.e. playing home or away games, score) should be considered to grasp a full understanding of how respiratory and muscular PE works in high level soccer players.

- Match internal load assessed through dRPE-ML barely varies throughout long periods of time (21 league and cup official matches disputed in an 8-week in-season period). The fact that the dRPE-ML does not change significantly from closely scheduled matches may be due to our having allowed a post-match recovery of at least 72 hours.

# Chapter 5

## Practical purposes

# CHAPTER 5. PRACTICAL PURPOSES

The practical applications showed in this doctoral thesis provide useful information about internal load and PE in professional soccer players. Thus, particularly we displayed the following ones:

- Since training strategies designed for N-S players in the first training session of the week are not sufficient to compensate for the effects of participating in the weekly TL, technical staff should considerer the inclusion of compensatory training strategies during other days of the week. As for all the ST, these extra contents should ensure training-to-match recovery and prevent fatigue prior to disputing the match.

- Taking into account both aspects of TL and ML showed by the professional soccer players, our data also highlight the importance of monitoring internal load during matches and training sessions throughout the dRPE to help manage workloads and prescribe appropriate training and recovery activities to support coaches and practitioners. The dRPE could be a useful tool for monitoring changes in training and match sessions and, finally, implementing specific post-match recovery strategies throughout the season.

- The existing variability between players' game position and the variability shown among games, taking into account dPE deconstruction for professional soccer players, outlines the need to stipulate specific week training plans for the different on-field positions of players. Implementation of individualized sessions throughout the week, according to the specific position of players, seems to be necessary in order to increase players' performance at the most-demanding session of the week, that is, the match.

- The small variability shown by the dRPE-ML of professional soccer players between consecutive league and CupM throughout of one season suggests that a 72-hour post-match recovery enables players to fully recover their physical and physiological levels and, thus, regain their optimal conditions to compete in another match. At the same time, the strategies followed in pre- and post-match training plans may have some part in players' recovery. The current data of this study shows trainers and trainees the fact that they may be able to reduce post-game recovery times and use it to increase the time allotted to physical condition training.

# Chapter 6

## The doctoral thesis limitations

# CHAPTER 6. THE DOCTORAL THESIS LIMITATIONS

The limitations of this doctoral thesis do not undermine the quality of the present project. Nevertheless, it seems worth it to mention them at this point so that future research lines and correct any possible error of the present ones. Thus, the limitations were the following ones:

- The evaluation of load through dRPE has meant the absence of other quantification methods of external load. Due to external reasons, we were prevented from having the possibility to complete the research with the study of external load.

- Being unable to carry out measurement tests of physical condition at the end of the season means that it was impossible to complete a whole season. This constitutes a slight diminishment but it did not render it invalid. A decision taken by the team's management staff, external to the coaching staff, hindered the aim of the project.

- The statistical perspective taken in this thesis has led and redirected the thoughts and development of the doctoral thesis, since it has caused debate with the reviewers that agreed to review the articles that make this thesis. This interesting lack of universal agreement on this point has enriched my knowledge on the matter and it has also awoken the will to continue exploring new alternatives in the field of statistics. This could also imply the development of future new and enriching researching lines in sport science.

- The reduced sample size used in this project has been an obstacle at the time of evaluating the data gathered. A larger quantification, including data from different professional teams, would have given greater weight to the results shown. Nonetheless, the competitive level of such a special sample as players (professional soccer players) meant an added value onto the elaboration of this doctoral thesis, which was already a very complex process for just one team.

# Chapter 7

## Future research lines

# CHAPTER 7. FUTURE RESEARCH LINES

The research lines of this doctoral thesis identified, as priorities in order to deepen future knowledge were the following ones:

- Taking into consideration the limitations of not assessing EL for reasons external to this study, it would be interesting to compare IL quantification for training and match sessions to external load quantification in the same sessions, so that the relationship between both methods can be observed.

- The conclusions obtained through this thesis, all of them focused on soccer, reaffirm the suitability of dRPE methods in this sport, which leads us to think that implementing this research methodology in other team sports such as basketball or handball could also be interesting and could enable the comparison of results between sports.

- This doctoral thesis has been focused on soccer at professional level. It would also be interesting to apply this research to amateur soccer, as it is also easier to access and gather more information. The size of the samples that could be obtained would be greater as there are a higher number of amateur soccer teams than professional ones. In addition, financial means for these teams are scarce, so they have lower financial capacity for the quantification of players' load. Data could also be compared between teams of professional and amateur teams.

- In line with what was just mentioned, amateur soccer players do not have exclusive dedication to sport, so they are very often exposed to other types of loads derived from their works and daily activities. It would also be interesting to find out how these external situations affect load levels in players so that the prior level of load with which a player faces a training or match session can also be known.

# Chapter 8

## Attachments

# CHAPTER 8. ATTACHMENTS

The project attachments, which were developed throughout this doctoral thesis, they are shown here.

### *Subchapter 8.1. Reference lists of the thesis articles*

Azcárate, U., Yanci, J., & Los Arcos, A. (2018). Influence of match playing time and the length of the between-match microcycle in Spanish professional soccer players' perceived training load. *Science and Medicine in Football*, 2(1), 23-28.

Azcárate, U., Los Arcos, A., Jiménez-Reyes, P., & Yanci, J., (2020). Are acceleration and cardiovascular capacities related to perceived load in professional soccer players?. *Research in Sports Medicine,* 28(1), 27-41.

Azcárate, U., Yanci, J., & Los Arcos, A. (2019). Differentiated perceived match load and its variability according to playing position in professional soccer players during an entire season. *Kinesiology,* (In press)

Azcárate, U., Los Arcos, A., & Yanci, J.,. Variability of professional soccer players' perceived match load after successive matches. *International Journal of Sport Psychology*, (under review)

## *Subchapter 8.2. Quality index of journals where the articles were published*

| Journal Title | Abbreviation | ISSN | Country | Web | Metric IF | Category | IF | Quartile |
|---|---|---|---|---|---|---|---|---|
| Science and Medicine in Football | Sci Med Football | 2473-3938 | England | https://www.tandfonline.com/loi/rsmf20 | Scopus | Sport science | - | 4 |
| Research in Sports Medicine | RSM | 1543-8635 | United Kingdom | https://www.tandfonline.com/toc/gspm20/current | JCR | Sport science | 2.549 | 2 |
| Kinesiology | Kinesiol | 1331-1441 | Croatia | https://hrcak.srce.hr/ojs/index.php/kinesiology/index | JCR | Sport science | 1.383 | 3 |
| International Journal of Sport Psychology | IJSP | 1331-1441 | Italy | http://www.ijsp-online.com | JCR | Sport science | 0.662 | 3 |

ISSN = International Standard Serial Number; IF = Journal impact factor.

### ***Subchapter 8.3. Level of compliance with current regulations for thesis elaborated via a compendium of articles.***

In compliance with the academic commission that regulates the doctoral thesis program in Physical and Sport Activity, the current legislation (Art. 7 of Doctoral management normative, BOPV June 27th 2013) for the UPV/EHU, regarding the elaboration of thesis through a compendium of articles establishes that:

a) It Social Sciences, a PhD student must have, at least, three publications as first author.
b) In relation to this, these three publication must make for a total of two points, although its distribution can be decided by the PhD student.

| **Journal** | **Journal type** | **Publication status** | **Quantitative points** |
|---|---|---|---|
| Sci Med Football | Scopus Q2 | Published | 0.75 |
| RSM | JCR Q2 | Published | 1 |
| Kinesiol | JCR Q3 | In press | 1 |
| IJSP | JCR Q4 | In review | 0 |

***Total = 2.75***

## ***Subchapter 8.4. Publications related to the doctoral thesis in which has taken part the doctoral student.***

Azcárate, U., Los Arcos, A., & Yanci, J. (2018). Effects of training programs integrated only with football drills on the cardiovascular and neuromuscular performance of amateur footballer players (in Spanish). *Journal of Sport and Health Research*, 10(2), 251–256.

Yanci, J., Azcárate, U., & Los Arcos, A. (2017). Analysis of the repeated sprints ability with and without change of direction in professional soccer players (In Spanish). *Sport TK: Revista Euroamericana de Ciencias del Deporte,* 6(1), 51–56.

Azcárate, U., Los Arcos, A., & Yanci, J. (2016). Acceleration, change of direction ability and cardiovascular fitness differences in amateur soccer players according to the competition category (in Spanish). *Revista Universitaria de la Educación Física y el Deporte,* 9(9), 6–14.

Azcárate, U., & Yanci, J. (2016). Physical profile in amateur category soccer players according to field position (in Spanish). *Revista Española de Educación Física y Deportes,* 415

### *Subchapter 8.5. Editorial Board Member*

Editorial Board Member of Journal of Advances in Medicine Science. ISSN: 2591-7609 (Print) 2591-7617 (Online).

## ***Subchapter 8.6. Posters, oral presentation and abstracts submitted in scientific events***

Azcárate, U., Otaegi, A., Yanci, J., Rodriguez-Negro, J., Romaratezabala, E., & Los Arcos, A. (2018). Assessing mechanical variables over the acceleration phase in amateur soccer player. *Conference: 6th NSCA International Conference At: Madrid,* (Conference paper).

Azcárate, U., Otaegi, A., Yanci, J., Rodriguez-Negro, J., Romaratezabala, E., & Los Arcos, A. (2018). Relationship between sprinting and jumping performances according to season period in Spanish elite soccer players. *Conference: 6th NSCA International Conference At: Madrid,* (Conference paper).