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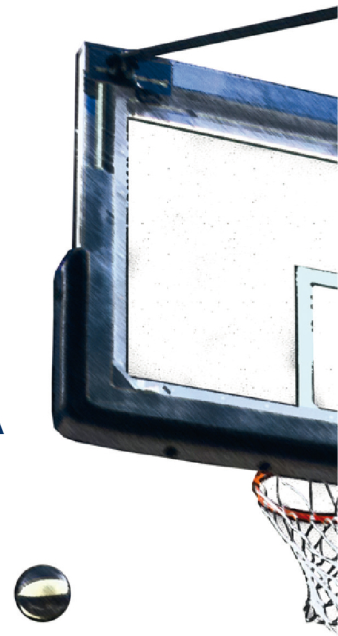

TESIS DOCTORAL

DEMANDAS FÍSICAS EN BALONCESTO DURANTE COMPETICIÓN MEDIANTE MICROTECNOLOGÍA: DE LOS PROMEDIOS A LOS ESCENARIOS DE MÁXIMA EXIGENCIA

DOCTORANDO

FRANC GARCÍA GARRIDO

Vitoria - Gasteiz 2021

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En Vitoria-Gasteiz, a 29 de marzo de2021

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«I’ve missed more than 9000 shots in my career. I’ve lost almost 300 games. Twenty-six times I’ve been trusted to take the game-winning shot and missed. I’ve failed over and over and over again in my life. And that is why I succeed»

Michael Jordan

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RESUMEN

La reciente irrupción de la microtecnología para la evaluación de las demandas físicas en los deportes colectivos ha supuesto un aumento en la cantidad de datos objetivos recogidos durante sesiones de entrenamiento y partido. En baloncesto, la imposibilidad de monitorización de la competición oficial profesional ha resultado en un amplio análisis de las demandas físicas basadas en valores promedios durante tareas y sesiones de entrenamiento, así como de partidos amistosos jugados en su mayoría durante pre-temporada en formatos de torneo comprimido. Por este motivo, los dos objetivos principales de la presente tesis fueron: 1) examinar las demandas físicas durante competición oficial de baloncesto, y 2) cuestionar el uso de los valores promedios y valorar el análisis de las demandas competitivas en función de los escenarios de máxima exigencia (EME). Un total de 88 jugadores profesionales y formativos (17,8 ± 5,2 años; 191,9 ± 14,0 cm; 82,7 ± 18,6 kg) de siete equipos distintos de la sección de baloncesto del Futbol Club Barcelona fueron monitorizados durante las temporadas 18/19 y 19/20 en entrenamientos y partidos oficiales de liga usando un sistema de posicionamiento local (Realtrack Systems, WIMU PRO™). Los parámetros para cuantificar las demandas físicas fueron: velocidad máxima, distancia y número de acciones > 18 $km \cdot h^{-1}$, distancia y número de aceleraciones y desaceleraciones > 2 $m \cdot s^{-2}$, *player load*, saltos > 3G e impactos > 8G. Los resultados de los diferentes estudios presentados demostraron que las demandas físicas son significativamente diferentes ($p<0.05$) entre posiciones de juego, cuartos y categorías de competición en baloncesto competitivo. Además, los datos analizados mostraron que los valores promedios subestiman ampliamente (diferencias entre 58 y 686%) los escenarios de máxima exigencia de 60 segundos en las diferentes categorías de competición estudiadas. En conclusión, las diferencias entre los factores que pueden modular las demandas físicas durante competición oficial tienen que ser consideradas para reforzar la aplicación de metodologías basadas en la individualización del proceso de preparación, especialmente en la estructura condicional durante periodos fuera de temporada y/o en jugadores con poca carga competitiva acumulada. Asimismo, los EME pueden complementar el análisis tradicional basado en los valores promedios para controlar mejor la prescripción de las sesiones de entrenamiento y optimizar el rendimiento individual y colectivo en partidos.

Palabras clave: Rendimiento deportivo; Sistema de posicionamiento local; Deporte colectivo; Carga externa.

ABSTRACT

The recent advancement of microtechnology has increased the quantity of objective data collected to evaluate the physical demands in team-sports during training sessions and matches. However, the impossibility of monitoring official competition in professional basketball has resulted in an extensive physical demands analysis based on averages during training drills and sessions, as well as friendly matches completed during pre-season in congested tournaments. For this reason, the two main goals of the present thesis were: 1) to examine the physical demands during official basketball competition, and 2) to question the use of averages and propose the analysis of physical game demands during the most demanding scenarios (MDS) of basketball match-play. A total of 88 professional and academy players (17.8 ± 5.2 years; 191.9 ± 14.0 cm; 82.7 ± 18.6 kg) from seven different teams of the basketball section in the Futbol Club Barcelona were monitored during training and official league matches in the 18/19 and 29/20 season using a local positioning system (Realtrack Systems, WIMU PRO™). The parameters used to quantify the physical demands were: Peak velocity, total distance, distance and number of actions > 18 $km \cdot h^{-1}$, distance and number of accelerations and decelerations > 2 $m \cdot s^{-2}$, player load, jumps > 3G and impacts > 8G. The results of the studies published showed that the physical demands are significantly different ($p<0.05$) across playing positions, game quarters and age-level categories during basketball competition. Furthermore, our data revealed that average values extensively underestimate (58-686% differences) the most demanding 60-s scenarios across the different age-levels analyzed. In conclusion, the differences between the factors that can modulate the physical demands during official competition should be considered to bolster the application of training methodologies based on individualization, especially in the physical capacity during off-season and/or with players with reduced competitive load accumulated. Likewise, the MDS can complement the traditional approach based on average values to better control the prescription of training sessions and optimize the individual and team performance during games.

Key words: Sports performance; Local positioning system, Team-sport; External load

I. SÍNTESIS

PREÁMBULO

El trabajo que se presenta se ajusta a la normativa de la Universidad del País Vasco / Euskal Herriko Unibertsitatea (UPV/EHU) como «tesis por compendio de publicaciones», cuya normativa de gestión de enseñanzas de doctorado puede ser encontrada en https://www.ehu.eus/es/web/estudiosdeposgrado-graduondokoikasketak/tesia-artikuluen-bildumaren-bidez.

Las referencias que componen la presente tesis son las siguientes:

1. García, F., Vázquez-Guerrero, J., Castellano, J., Casals, M., & Schelling, X. (2020). Differences in physical demands between game quarters and playing positions on professional basketball players during official competition. *Journal of Sports Science and Medicine* (Factor de impacto 2019: 1.81 / Cuartil 2), 19(2), 256–263.
2. Vázquez-Guerrero, J., & García, F. (2020). Is it enough to use the traditional approach based on average values for basketball physical performance analysis? *European Journal of Sport Science* (Factor de impacto 2019: 2.78 / Cuartil 1), 1–18. https://doi.org/10.1080/17461391.2020.1838618
3. García, F., Castellano, J., Reche, X., & Vázquez-Guerrero, J. (2021). Average game physical demands and the most demanding scenarios of basketball competition in various age groups. *Journal of Human Kinetics* (Factor de impacto 2019: 1.67 / Cuartil 3). Ahead of Print.
4. García, F., Schelling, X., Castellano, J., Pla, F., & Vázquez-Guerrero, J. (2021). Comparison of the most demanding scenarios during different in-season training sessions and official matches in professional basketball players. *Biology of Sport* (Factor de impacto 2019: 2.00 / Cuartil 2), 39(2). https://doi.org/10.5114/biolsport.2022.104064.

1. INTRODUCCIÓN

El área de rendimiento deportivo del Futbol Club Barcelona (FCB), influenciada principalmente por la ideología ecológico-holística basada en la teoría general de los sistemas dinámicos complejos y utilizada por el profesor Paco Seirul·lo (2017), ha desarrollado y aplicado una metodología centrada en la individualización, la variabilidad, la especificidad, el abordaje global y el aprendizaje diferencial, entre otros elementos, con el objetivo de preparar al ser humano deportista para rendir en un deporte de equipo: el entrenamiento estructurado (Tarragó, Massafret-Marimón, Seirul·lo & Cos, 2019). El entrenamiento estructurado es, por definición, una propuesta específica de entrenamiento que se organiza en dos áreas de actuación: el entrenamiento coadyuvante y entrenamiento optimizador (Figura 1). Así como el entrenamiento coadyuvante prepara al deportista para entrenar y poder optimizar las estructuras y sistemas que permitirán conseguir un rendimiento deportivo posterior (Gómez, Roqueta, Tarragó, Seirul·lo & Cos, 2019), el entrenamiento optimizador se basa en la especificidad deportiva y prepara al deportista para la competición (Pons, Martín-García, Guitart, Guerrero, Tarragó & Seirul·lo, 2020).

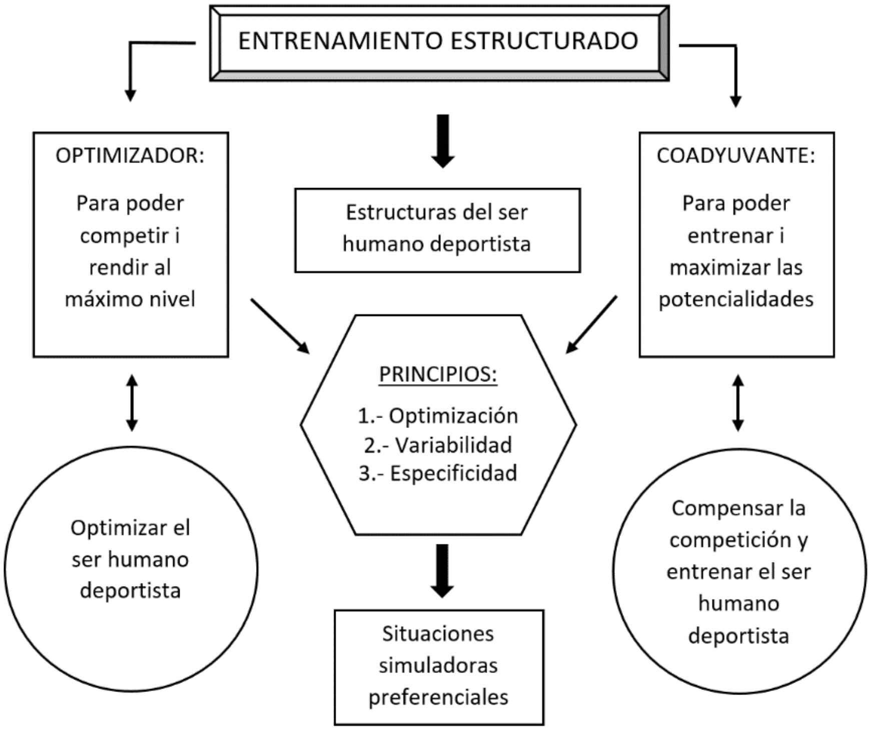

Figura 1. *Principios del entrenamiento estructurado. Adaptado de Tarragó et al. (2019)*

Además de esta división de concepto, el entrenamiento estructurado debe su nombre a las múltiples estructuras que se pueden identificar en el ser humano deportista (Figura 2). Debido a que todas estas estructuras intervienen siempre en mayor o menor grado en el rendimiento deportivo, la concepción holística propone su integración global en el entrenamiento. Asimismo, la optimización del entrenamiento estructurado se consigue mediante la interacción, cooperación y sinergia de todas las estructuras del ser humano deportista, el cual persigue una optimización global y funcional con su entorno competitivo específico (Seirul·lo, 2017; Tarragó et al., 2019).

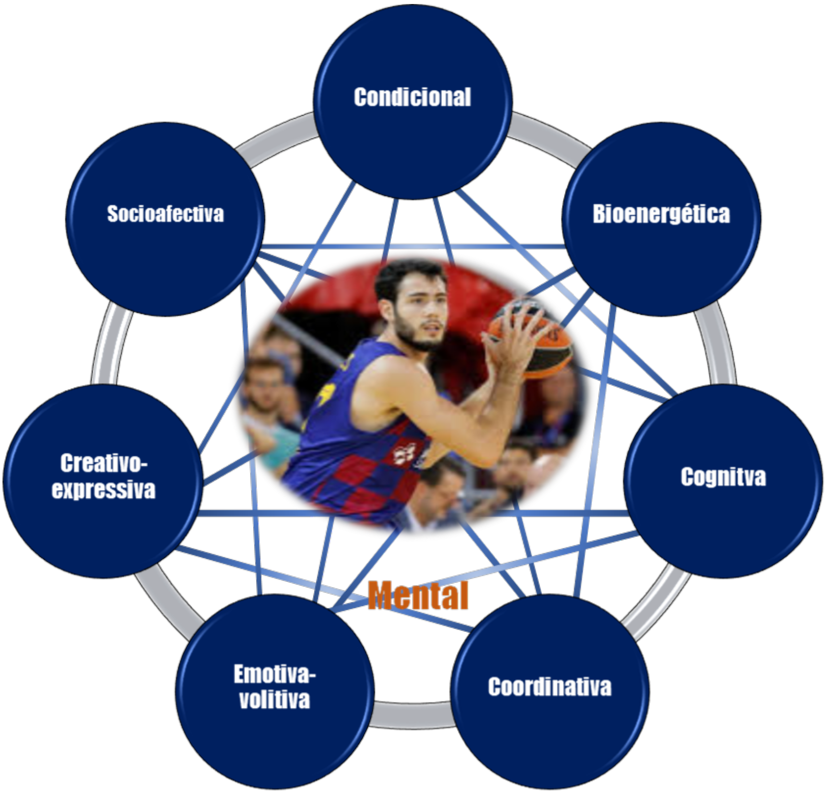

Figura 2. *Estructuras que conforman el ser humano deportista. Adaptado de Tarragó et al. (2019)*

Sin dejar de lado el resto de las estructuras que componen el ser humano deportista, el área de rendimiento del FCB ha realizado un gran esfuerzo para cuantificar la estructura condicional. Desde el verano de 2016, un total de 15 equipos de los cinco deportes profesionales del FCB (fútbol, baloncesto, balonmano, futbol sala y hockey patines) están utilizando el dispositivo WIMU PRO™ (Realtrack Systems, Almería, España), el cual combina sistemas de posicionamiento global (GPS) y/o local (LPS) con microtecnología inercial para cuantificar las demandas físicas durante entrenamientos y competiciones.

Respecto al baloncesto, uno de los deportes colectivos más populares en el mundo (Hulteen et al., 2017), cabe destacar que los dos equipos profesionales del FCB utilizan WIMU PRO™ con el objetivo de controlar la carga externa y poder optimizar la prescripción del proceso de entrenamiento, así como el posterior aumento en la disponibilidad de los jugadores, reducción del riesgo lesivo (Caparrós, Casals, Solana & Peña, 2018) y optimización del rendimiento individual y colectivo en competición. Además, a partir de la temporada 18/19, las cuatro principales categorías del baloncesto formativo del club (mini o Sub-12, infantil o Sub-14, cadete o Sub-16 y junior o Sub-18) también han sido monitorizadas durante partidos de liga para obtener datos de la sesión de máxima intensidad y especificidad posible: la competición oficial. Si bien es importante monitorizar las demandas físicas durante el proceso de entrenamiento (Aoki et al., 2017), es de vital importancia poder cuantificar la exigencia física durante competición oficial para poder optimizar la preparación de los deportistas (Fox, Scanlan & Stanton, 2017). Esta necesidad crece a medida que la cantidad de partidos competitivos por semana aumentan, como es el caso de los equipos que combinan competiciones de muy alto nivel. A modo de ejemplo, el primer equipo de baloncesto del FCB compite regularmente en Euroliga (primera división europea) y en la liga de la Asociación de Clubes de Baloncesto (ACB; primera división española) disputando entre dos y tres partidos por semana.

La creciente carga competitiva de la Euroliga (1ª división europea), con el reciente (octubre 2016) cambio de formato y la mayoría de equipos completando entre dos y tres partidos por semana combinando competiciones, junto a una sólida voluntad de optimización del proceso de entrenamiento mediante el conocimiento de las demandas físicas durante competición en las diferentes categorías donde la sección de baloncesto del FCB participa, ha desencadenado la motivación necesaria para la realización de la presente tesis. La figura 3 presenta la estructura del proyecto de doctorado, con una extensa revisión bibliográfica sobre microtecnología en baloncesto competitivo. En el marco teórico, el lector encontrará un repaso de la evolución de la tecnología aplicada al baloncesto desde los métodos de video-análisis hasta el uso de microtecnología (e.g., unidades de medición inercial y sistemas de posicionamiento local [LPS]) para la cuantificación de las demandas físicas durante la competición o el entrenamiento. Además, el marco teórico también ofrecerá una reflexión crítica sobre el uso de los promedios para la descripción de las demandas físicas durante entrenamientos y partidos y la posibilidad de complementación con los datos de las situaciones máximas o escenarios de máxima exigencia. Por último, el marco teórico presentará una propuesta para la clasificación de las diferentes categorías de competición en baloncesto (e.g., amateur o profesional) y una aproximación a las diferencias existentes entre las sesiones de entrenamiento y partidos, así como la dificultad comparativa debido a la gran variabilidad entre las sesiones preparatorias y sus diferentes tareas analizadas.

A partir del marco teórico, la presente tesis abordará un total de cuatro objetivos (Figura 3). Todas las preguntas intentarán ser respondidas en base a los datos de las demandas físicas durante competición de los equipos de baloncesto del FCB durante las temporadas 18/19 y 19/20 registrados mediante la tecnología que ofrece la empresa Realtrack Systems con el dispositivo WIMU PRO™.

El primero de los objetivos describirá las demandas físicas durante competición oficial de baloncesto mediante valores promedios, y se buscará poder responder a la pregunta: ¿existen diferencias entre posiciones y periodos de juego (cuartos) en jugadores profesionales?

En segundo lugar, se compararán los valores promedios con los valores de los escenarios de máxima exigencia (EME) en jugadores profesionales de baloncesto, indicando la importancia del análisis de las demandas pico durante competición. La pregunta a responder es: ¿qué diferencias existen entre valores promedios y EME durante la competición oficial de baloncesto?

También en el ámbito profesional del baloncesto, un tercer objetivo será el análisis de las demandas físicas en las diferentes categorías de formación de la sección de baloncesto del FCB. En este sentido, la competición oficial de hasta cinco niveles diferentes será descrita y comparada mediante promedios y EME. En este caso, la pregunta principal es: ¿qué diferencias existen en las demandas físicas durante competición entre las cinco principales categorías de formación (Sub-12 hasta sénior) existentes en baloncesto?

Por último, y volviendo a la voluntad inicial de optimización del proceso de entrenamiento, los EME se utilizarán para comparar las demandas pico en competición oficial y los diferentes tipos de sesiones de entrenamiento y poder responder a la pregunta: ¿se alcanzan los EME de competición en el proceso de entrenamiento?

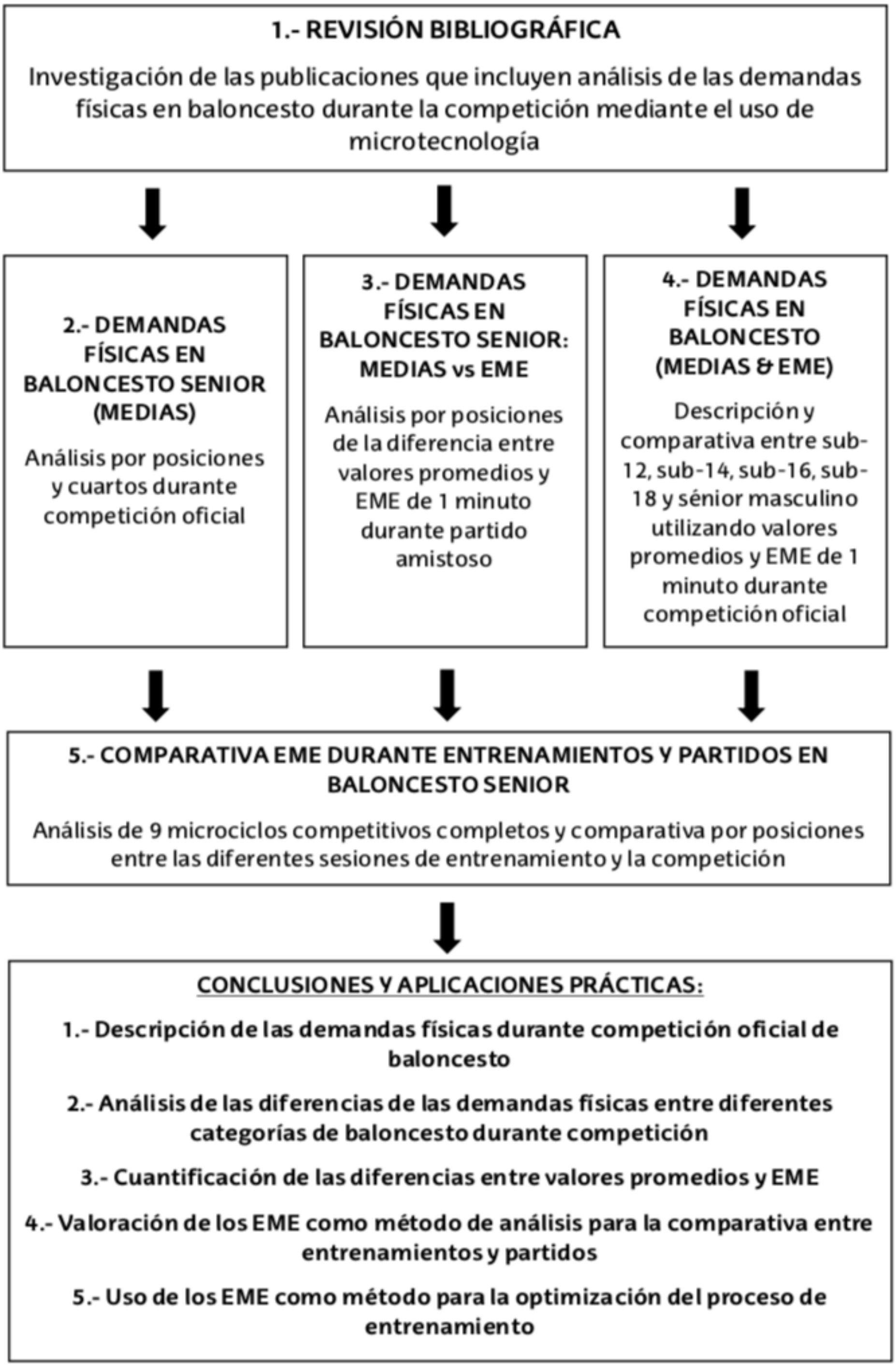

Figura 3. *Esquema del proyecto de tesis*

2. MARCO TEÓRICO

2.1. Sistemas de registro

Mediante sistemas de video-análisis (Stojanović et al., 2018), las demandas físicas durante partidos competitivos han sido ampliamente cuantificadas en jugadores y jugadoras de baloncesto de distinto nivel y categoría desde 1995 (McInnes, Carlson, Jones & McKenna et al., 1995; Stojanović, 2018). Aunque se ha demostrado una validez y fiabilidad alta de este método (Barris & Button, 2008), la gran inversión de tiempo, impidiendo la toma de decisiones diaria y la aparición de otras estrategias más eficientes basadas en microtecnología, ha limitado su uso y disminuido su popularidad. De este modo, Montgomery, Pyne & Minahan (2010) fue el primer estudio en utilizar unidades de medición inercial, o *inertial measurements units* (IMUs), para obtener datos derivados de un acelerómetro de tres ejes con una frecuencia de muestreo alta (100 Hz) para la descripción y cuantificación de las demandas físicas durante entrenamientos y partidos de baloncesto en jugadores jóvenes (Sub-20) mediante el uso de la variable de *body load* (Boyd, Ball & Aughey, 2011) o *player load* (Nicolella, Torres-Ronda, Saylor & Schelling, 2013). Microtecnología similar (dispositivos inerciales que integran acelerómetro, giroscopio y manómetro) también ha sido utilizada para medir variables tales como aceleraciones, desaceleraciones, pasos, saltos e impactos para comparar las demandas físicas de entrenamiento y competición en jugadoras amateur (Reina, Mancha, Feu & Ibáñez, 2017) y jugadores profesionales de baloncesto durante torneos de formato intensivo en pre-temporada (Svilar, Castellano & Jukić, 2018; Vázquez-Guerrero, Casamichana, Suarez-arrones & Rodas, 2018a). Cabe destacar que la información proveniente de los IMUs no permite cuantificar acciones musculares isométricas (e.g., luchas y contactos entre jugadores), las cuales pueden llegar a demandar una gran exigencia aún sin basarse en la aceleración. Recientemente, los rápidos avances en tecnología han permitido complementar la información de las demandas en baloncesto procedente de los IMUs con otros parámetros como la distancia total, distancia recorrida a alta velocidad o la velocidad máxima gracias a los GPS y LPS.

Puente, Abián-Vicén, Areces, López & del Coso (2017) ha sido el único estudio publicado que utilizó el sistema GPS para analizar las demandas físicas en jugadores de baloncesto durante competición. Sin embargo, las dos principales limitaciones metodológicas de este estudio fueron el tipo de tecnología utilizada y el tipo de competición. Por un lado, el GPS tienen el principal inconveniente de que no puede ser utilizado por los deportes de pista cubierta (Cummins, Orr, O'Connor & West, 2013), además de ser un sistema con un coste muy elevado. Por otro lado, el estudio mencionado cuantificó las distancias recorridas a diferentes intensidades en jugadores durante partidos amistosos con reglamento modificado jugados en una pista al descubierto (Puente et al., 2017). Además de la limitación del tipo de instalación, la prohibición de usar microtecnología en las principales ligas de baloncesto mundial, como son la Euroliga y la *National Basketball Association* (NBA), han dificultado la realización de investigaciones durante competición oficial en baloncesto profesional. Sin embargo, tecnología que combina IMUs con LPS ha permitido el análisis de las demandas físicas en categoría Sub-18 tanto en baloncesto femenino (Tabla 1) como en masculino (Tablas 2 y 3).

Después de una revisión exhaustiva de la bibliografía disponible sobre el análisis de las demandas físicas en competición de baloncesto, el presente doctorando ha detectado una falta de información respecto al uso de microtecnología durante competición oficial tanto en jugadores sénior (profesionales, semi-profesionales o amateurs) como en categorías de formación (Petway, Freitas, Calleja-González, Leal, & Alcaraz, 2020).

Tabla 1. *Estudios publicados sobre el análisis de las demandas físicas mediante el uso de microtecnología durante competición de baloncesto femenino: valores promedios.*

Estudio	n	Participantes (Nivel)	Competición (n)	Marca	Tecnología	Variables
Reina et al., 2017	19	Amateur femenino (Nivel 2)	Fase final liga autonómica (Extremadura) (n=8)	Realtrack Systems	IMU	Pasos, impactos y saltos
Reina et al., 2019a	48	Sub-18 femenino (Nivel 2)	Fase final liga autonómica (Extremadura) (n=12)	Realtrack Systems	IMU y LPS	Distancia a diferentes velocidades, ACC, DEC, impactos, saltos y PL
Reina et al., 2019b	12	Sub-13 femenino (Nivel 2)	Liga autonómica española (Extremadura) (n=8)	Realtrack Systems	IMU	PL, pasos, impactos y saltos
Reina et al., 2019c	19	Amateur femenino (Nivel 2)	Fase final liga autonómica (Extremadura) (n=8)	Realtrack Systems	IMU	PL, pasos, impactos y saltos
Reina et al., 2019d	48	Sub-18 femenino (Nivel 2)	Fase final liga autonómica (Extremadura) (n=6)	Realtrack Systems	IMU	ACC y DEC
Reina et al., 2020b	48	Sub-18 femenino (Nivel 2)	Fase final liga autonómica (Extremadura) (n=6)	Realtrack Systems	LPS	Distancia a diferentes velocidades
Ransdell et al., 2020	6	Universitario femenino (Nivel 3)	Liga universitaria NCAA División 1 (n=144)	Catapult	IMU	PL, acciones alta intensidad y saltos
Portes et al., 2020	73	Sub-18 femenino y masculino (Nivel 2)	Final A4 Autonómica (n=12)	Realtrack Systems	IMU y LPS	Distancia total y a diferentes velocidades, ACC, DEC y PL

Nota: IMU = Unidades de medición inercial; LPS = Sistema de posicionamiento local; PL = *Player load*; ACC = Aceleraciones; DEC = Desaceleraciones.

2.2. Técnica de análisis

2.2.1. Promedios en el tiempo total y efectivo de juego

Mediante video-análisis, IMUs, GPS o LPS, los científicos del deporte analizan valores absolutos de diferentes variables de la demanda física de cada jugador (e.g., distancia total recorrida, distancia recorrida a alta velocidad, número de aceleraciones a alta intensidad) en un periodo de tiempo determinado, bien sea entrenamiento o competición (Martín-García, Gómez, Bradley, Cos & Casamichana, 2018a). Con el principal objetivo de analizar la intensidad de las variables registradas y su fluctuación durante el transcurso del partido, varios investigadores han relativizado el valor absoluto al tiempo total de juego, definido como el sumatorio de minutos que cada jugador permanece en pista durante el partido y que incluye interrupciones tales como faltas, violaciones, substituciones o tiros libres; una segunda opción para la normalización de los valores es la utilización del tiempo efectivo de juego, entendido como el sumatorio de minutos con el cronómetro en marcha durante el juego (Russell, Mclean, Impellizzeri, Strack & Coutts, 2020; Stojanović et al., 2018). En esta línea, una reciente investigación concluyó que las interrupciones en el juego eran proporcionales a la duración de la acción continua en baloncesto, mostrando cómo las acciones de corta duración (<16 s) fueron seguidas por pausas de corta duración (<14 s), y las acciones de larga duración (>46 s) provocaron pausas de mayor duración (>38 s) (Salazar & Castellano, 2020). De esta manera, las diferencias del tiempo total de juego entre partidos, medias partes o periodos podría alterar las comparaciones entre los valores relativos de las diferentes variables registradas (Castellano, Blanco-Villaseñor & Álvarez, 2011; Linke, Link, Weber & Lames, 2018; Zurutuza, Castellano, Echeazarra, Guridi & Casamichana, 2020).

Además del análisis de la intensidad y la afectación de la fatiga en los minutos finales de los deportes de equipo, los valores relativos al minuto también son de gran ayuda en deportes de pista cubierta sin limitación de substituciones para comparar las demandas físicas entre jugadores con distinto tiempo de juego total acumulado. La revisión de Stojanović et al. (2018) propuso analizar las demandas físicas en baloncesto durante competición mediante los dos métodos definidos anteriormente. Mientras que la evaluación de las demandas físicas mediante el tiempo efectivo de juego ayudaría en el desarrollo de entrenamiento específico para la competición, el uso del tiempo total sería importante para el desarrollo de planes de entrenamiento ecológicamente válidos. Si bien el reglamento FIBA especifica que se compite durante 40 minutos reglamentarios (tiempo efectivo de juego), la realidad es que los partidos suelen durar entre 100 y 120 min (tiempo total) teniendo en cuenta un total de 21 min entre periodos (1,5 min entre 1er y 2º cuarto y entre 3er y 4º cuarto; y 15 min entre 2º y 3er cuarto) y entre 10 y 14 posibles tiempos muertos de un minuto por partido entre los cinco disponibles por equipo y los 4 de televisión en los partidos televisados. Con estos datos disponibles, se puede decir que el tiempo total en baloncesto suele ser el doble del tiempo efectivo de juego.

A modo de ejemplo, el valor absoluto de 5000 m recorridos en un partido de baloncesto se podrá relativizar en función del tiempo efectivo de juego de ese jugador en concreto (e.g., 5000 m entre 30 min de juego = 166,7 $m{\cdot}min^{-1}$) o bien en función del tiempo total que el jugador haya permanecido en pista. (e.g., 5000 m entre 63 min de juego = 79,8 $m{\cdot}min^{-1}$). En consecuencia, parece de vital importancia conocer el método utilizado para normalizar los valores absolutos con los que poder comparar resultados.

Tabla 2. *Estudios publicados sobre el análisis de las demandas físicas mediante el uso de microtecnología durante competición de baloncesto masculino: valores promedios*

Estudio	n	Participantes (Nivel)	Competición (n)	Marca	Tecnología	Variables
Montgomery et al., 2010	11	Sub-20 masculino (Nivel 3)	Partidos amistosos (n=3)	Suunto Pro Team Pack	IMU	PL
Gómez-Carmona et al., 2019	94	Sub-18 masculino (Nivel 3)	Euroleague Basketball Next Generation Tournament 2017 (n=13)	Realtrack Systems	IMU y LPS	Distancia a diferentes velocidades, ACC, DEC, PL, pasos, saltos, potencia metabólica
Pino-Ortega et al., 2019	94	Sub-18 masculino (Nivel 3)	Euroleague Basketball Next Generation Tournament 2017 (n=13)	Realtrack Systems	IMU y LPS	Distancia a diferentes velocidades, ACC, DEC, PL, pasos, saltos, potencia metabólica
Vázquez-Guerrero et al., 2019a	94	Sub-18 masculino (Nivel 3)	Euroleague Basketball Next Generation Tournament 2017 (n=13)	Realtrack Systems	IMU y LPS	Distancia total, distancia a diferentes velocidades, PL, VM, ACC y DEC
Vázquez-Guerrero et al., 2019b	94	Sub-18 masculino (Nivel 3)	Euroleague Basketball Next Generation Tournament 2017 (n=13)	Realtrack Systems	IMU y LPS	Distancia total, Distancia a diferentes velocidades, PL, VM, ACC y DEC
Vázquez-Guerrero et al., 2019c	94	Sub-18 masculino (Nivel 3)	Euroleague Basketball Next Generation Tournament 2017 (n=13)	Realtrack Systems	IMU y LPS	Distancia total, distancia a diferentes velocidades y PL
Puente et al., 2017	25	Semi-profesional masculino (Nivel 4)	Partidos amistosos. Simulación normativa FIBA (n=1-3)	GPSports	IMU y GPS	Velocidad, impactos, ACC y DEC

Tabla 2. *Estudios publicados sobre el análisis de las demandas físicas mediante el uso de microtecnología durante competición de baloncesto masculino: valores promedios (continuación)*

Estudio	n	Participantes (Nivel)	Competición (n)	Marca	Tecnología	Variables
Scanlan et al., 2019	5	Semi-profesional masculino (Nivel 4)	Queensland Basketball League (Australia) (n=19)	Catapult	IMU	PL, ACC, DEC, CDD y saltos
Fox et al., 2019	15	Semi-profesional masculino (Nivel 4)	Partidos amistoso (Australia) (n=2)	Catapult	IMU	PL y distancia equivalente estimada
Leicht et al., 2019	6	Semi-profesional masculino (Nivel 4)	Queensland Basketball League (Australia) (n=1)	Catapult	IMU	PL
Fox et al., 2020c,e	8	Semi-profesional masculino (Nivel 4)	Queensland Basketball League (Australia) (n=18)	Catapult	IMU	PL, ACC, DEC, CDD y saltos
Svilar et al., 2018	16	Profesional masculino (Nivel 5)	Partidos amistosos pre-temporada (n=5)	Catapult	IMU	PL, ACC, DEC, CDD y saltos
Vázquez-Guerrero et al., 2018	12	Profesional masculino (Nivel 5)	Liga autonómica (Cataluña) (n=2)	StatSports	IMU	PL, ACC y DEC
Salazar et al., 2020	17	Profesional masculino (Nivel 5)	Partidos amistosos pre-temporada (n=5)	Catapult	IMU	PL, ACC, DEC, CDD y saltos

Nota: IMU = Unidades de medición inercial; LPS = Sistema de posicionamiento local; PL = *Player load*; ACC = Aceleraciones; DEC = Desaceleraciones; VM = Velocidad máxima.

2.2.2. Escenarios de máxima exigencia

Si bien el método más común para analizar las demandas físicas durante competición en baloncesto se ha basado en el estudio de los promedios o media de valores (Tablas 1 y 2), estudios recientes (Fernández, Novelles, Tarragó & Reche, 2020; Illa, Fernández, Tarragó & Reche, 2020; Martín-García, Casamichana, Gómez, Cos & Gabbett, 2018b; Vázquez-Guerrero, Ayala-Rodríguez, García & Sampaio, 2020a; Whitehead, Till, Weaving & Jones, 2018) proponen utilizar la técnica del promedio móvil o *rolling/moving average* para describir los escenarios de máxima exigencia (EME), también llamados *most demading scenarios* (Vázquez-Guerrero et al., 2020a), *most demanding passages* (Salazar & Castellano, 2019) o *peak demands* (Alonso, Miranda, Zhang, Sosa & Trapero, 2020; Fox, Conte, Stanton, Mclean & Scanlan, 2020). Esta técnica de análisis permite una descripción más válida sobre los periodos en los que la respuesta condicional de los jugadores es altamente demandada, describiendo el mayor valor alcanzado en cualquier variable de demanda física (e.g., distancia total, distancia a alta intensidad o número de aceleraciones) durante ventanas temporales previamente definidas (e.g., 30, 60 o 120 s).

En baloncesto, el uso tradicional de promedios se ha mostrado significativamente inferior al valor del EME (Vázquez-Guerrero et al., 2019c; Vázquez-Guerrero et al., 2020a). A modo de ejemplo, dos estudios realizados con los mismos jugadores de baloncesto Sub-18 durante un torneo oficial de nivel europeo muestran un incremento aproximado del 65% en distancia total recorrida y 250% en el número de aceleraciones de alta intensidad al comparar los valores medios por minuto (distancia total: 68,2-74,4 $m \cdot min^{-1}$; número de aceleraciones: 1,6-2 $n \cdot min^{-1}$) con el EME de un minuto (distancia total: 113,0-123,4 $m \cdot min^{-1}$; número de aceleraciones: 5,2-7,3 $n \cdot min^{-1}$) en Vázquez-Guerrero et al., (2019c) y (2020a). En consecuencia, la utilización del método tradicional basado en el cálculo de los promedios para cuantificar las demandas físicas en competición y, así diseñar las taras de entrenamiento, podría resultar en una inadecuada preparación de los jugadores para soportar adecuadamente los EME durante competición.

Además de la posible optimización del proceso de entrenamiento, los EME también podrían ser utilizados en los procesos de incorporación al juego después de sufrir una lesión con el objetivo de alcanzar los valores requeridos durante la competición oficial. Como se muestra en la Tabla 3, existe muy poca bibliografía que analice las demandas físicas en baloncesto durante competición mediante EME.

Tabla 3. *Estudios publicados sobre el análisis de las demandas físicas mediante el uso de microtecnología durante competición de baloncesto masculino: escenarios de máxima exigencia*

Estudio	n	Participantes (Nivel)	Competición (n)	Marca	Tecnología	Variables
Vázquez-Guerrero et al., 2020a	94	Sub-18 masculino (Nivel 3)	Euroleague Basketball Next Generation Tournament 2017 (n=13)	Realtrack Systems	IMU y LPS	Distancia total, distancia a diferentes velocidades, ACC y DEC
Alonso et al. 2020	12	Sub-18 masculino (Nivel 3)	Liga autonómica española (Madrid) (n=8)	Catapult	IMU	PL
Salazar y Castellano, 2019	9	Semi-profesional masculino (Nivel 4)	Liga LEB plata (3ª división española) (n=1)	Catapult	IMU y LPS	Distancia y PL
Fox et al., 2020a,b	8	Semi-profesional masculino (Nivel 4)	Queensland Basketball League (Australia) (n=15)	Catapult	IMU	PL
Fox et al., 2020d	8	Semi-profesional masculino (Nivel 4)	Queensland Basketball League (Australia) (n=18)	Catapult	IMU	PL, ACC, DEC, COD y saltos

Nota: IMU = Unidades de medición inercial; LPS = Sistema de posicionamiento local; PL = *Player load*; ACC = Aceleraciones; DEC = Desaceleraciones

2.3. Categorías de competición

Si bien es muy importante la monitorización de las demandas físicas de los jugadores durante baloncesto competitivo, también parece crucial entender las características de estos jugadores y el contexto en el que compiten. A modo de ejemplo, Petway et al. (2020) concluyó que jugadores élite podrían competir de manera más eficiente después de mostrar valores promedios y totales de demandas físicas inferiores a jugadores semi-élite y de formación, aun mostrando velocidades y aceleraciones pico más elevadas. A modo de detalle, la revisión sistemática de Petway et al. (2020) mencionó que jugadores de nivel élite recorrieron, de media, menos distancia total (4,369 m) en comparación a jugadores semi-élite (5,377 m) y de formación (4,369 m), así como jugadores élite mostraron una velocidad máxima (8,1 $m \cdot s^{-2}$) superior a jugadores semi-élite (6,2 $m \cdot s^{-2}$).

La distinción más sencilla para organizar las categorías de competición parece ser diferenciar entre jugadores mayores (adultos, sénior) y menores de 18 años de edad, también nombrados jugadores jóvenes o jugadores en etapas de formación (DiFiori et al., 2018). Aunque sencilla y de fácil comprensión, esta división de los participantes es poco precisa para entender el contexto de la competición. Una segunda opción más detallada sería la propuesta por Petway et al. (2020) en la que los equipos se clasificaron en élite, sub-élite y jóvenes. Las dos principales limitaciones de esta clasificación son que jugadores profesionales de baloncesto podrían ser considerados élite o sub-élite en función de criterios subjetivos, y que todos los jugadores menores de 19 años fueron clasificados como jóvenes. Para mejorar este sistema de clasificación, la revisión de Russell et al. (2020) propone organizar a los jugadores en función de cinco categorías de competición descritas con detalle y mostradas en la Tabla 4.

Tabla 4. *Clasificación de los niveles de competición en baloncesto. Adaptado de Russell et al. (2020)*

Nivel competitivo	Descripción	Características de los jugadores	Competición
1	Participantes sedentarios o desentrenados	Jugadores adultos	No oficial
2	Jugadores de nivel medio/bajo	Jugadores recreacionales o menores de 18 años	Regional; Autonómica
3	Jugadores jóvenes de nivel alto	Jugadores altamente entrenados	Internacional; NCAA
4	Jugadores semi-profesionales	Jugadores altamente entrenados	Semi-profesional
5	Jugadores profesionales	Jugadores con contrato a jornada completa	Profesional

Nota: NCAA = Competición universitaria de Estados Unidos (*National Collegiate Athletic Association*).

Siguiendo los niveles propuestos por Russell et al. (2020), la presente tesis ha podido identificar un total de siete estudios (Tabla 2) donde jugadoras Sub-13 (n=1), Sub-18 (n=4) y amateur (n=2) fueron analizadas durante competición oficial autonómica (nivel 2) mediante microtecnología (IMUs y/o LPS). En concreto, el único estudio en niñas Sub-13 (Reina, García-Rubio, Antúnez, Courel-Ibáñez & Ibáñez, 2019b) demostró la variabilidad de concentración de carga en variables inerciales como *player load*, pasos, saltos e impactos durante diferentes sesiones de la semana y su similitud con la competición. Además, hasta un total de tres estudios (Reina, García-Rubio, Antúnez, Córdoba & Ibáñez, 2019a; Reina, García-Rubio, Pino-Ortega, & Ibáñez, 2019d; Reina, García-Rubio & Ibáñez, 2020b) monitorizaron a 48 jugadoras Sub-18 durante seis partidos en tres días consecutivos durante un torneo final de Extremadura para establecer perfiles de velocidad, aceleración y desaceleración en función de posiciones de juego (exteriores, aleros/ala-pívots y pívots) durante competición oficial. También en la comunidad de Extremadura, dos investigaciones (Reina et al., 2017; Reina, García-Rubio, Feu & Ibañez, 2019c) analizaron la carga de 10 jugadoras de un mismo equipo de baloncesto femenino amateur en entrenamiento y partidos mediante IMUs para concluir que variables como *player load*, pasos e impactos por minuto fueron superiores en competición oficial. Por último, Portes et al. (2020) comparó las demandas físicas de cuatro equipos femeninos y dos equipos masculinos Sub-18 durante el torneo final autonómico de la Comunidad de Madrid concluyendo múltiples diferencias significativas entre sexos en variables como distancia a diferentes velocidades y número de aceleraciones y desaceleraciones.

Aumentado el nivel de exigencia competitiva del nivel 2 al 3 y centrando el análisis en jugadores jóvenes de nivel avanzado, la presente tesis ha identificado un total de nueve investigaciones. Además del estudio pionero de Montgomery et al. (2010), mencionado al inicio del marco teórico, Ransdell et al. (2020) publicó el perfil competitivo de un equipo de baloncesto universitario femenino de Estados Unidos (NCAA) compitiendo en división 1 durante cuatro años y monitorizando variables inerciales durante 144 partidos oficiales. En el baloncesto masculino, hasta un total de seis investigaciones han utilizado los datos del *Euroleague Basketball Next Generation Tournament 2017* para analizar distintas variables derivadas de LPS y IMUs en función de diversos factores contextuales como las posiciones de juego, los cuartos de partido, el nivel del equipo rival o el marcador mediante los valores promedios (tiempo total) o los EME. Cabe destacar que durante este torneo de categoría Sub-18 se monitorizó a un total de 94 jugadores distribuidos en seis equipos, los cuales completaron 13 partidos durante cuatro días seguidos (Tabla 3). Por último, Alonso et al. (2020) también utilizó los EME para analizar las demandas pico mediante *player load* en diferentes ventanas temporales (1, 5 y 10 min) en jugadores internacionales Sub-

18 concluyendo que los valores promedios subestiman los escenarios más exigentes durante competición.

Aunque las demandas físicas de jugadores y jugadoras junior (Sub-18) durante partidos de baloncesto han sido ampliamente descritas (Tabla 2 y 3), la bibliografía disponible en categorías inferiores sigue siendo muy escasa. Asimismo, la comparativa de las demandas físicas entre diferentes grupos de edad es importante para entender las necesidades competitivas específicas, adaptar la planificación del entrenamiento y optimizar el proceso de identificación de talento (Vaeyens, Lenoir, Williams & Philippaerts, 2008). A modo de ejemplo, se ha demostrado que en fútbol existe una relación positiva entre la distancia total recorrida y la edad (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010), así como se ha detectado una mejora significativa en la capacidad para realizar esprines entre las categorías Sub-14 y Sub-15. Debido a que la edad media para el inicio de la pubertad para chicos se encuentra en 13,5 años (Stratton, Reilly, Williams & Richardson, 2004), se presume que el estado madurativo de los jugadores podría influenciar directamente su rendimiento físico en competición. Hasta la fecha, no existe literatura científica que haya analizado las demandas físicas de jugadores de diferentes categorías de edad durante partidos de baloncesto mediante el uso de los EME y del método tradicional de valores medios.

Hasta la fecha, el mayor número de estudios (n=10) sobre la monitorización de las demandas físicas mediante microtecnología en baloncesto competitivo han sido identificados en jugadores de baloncesto de nivel 4 o semi-profesionales. Si bien el estudio de Puente et al. (2017) fue pionero en la utilización de sistemas de posicionamiento y el estudio preliminar de Salazar y Castellano (2019) incorporó el concepto de EME, un total de ocho estudios se han desarrollado con jugadores de la liga semi-profesional de Australia (*Queensland Basketball League*) para monitorizar variables relacionadas con IMUs (e.g., *player load*, aceleraciones, desacelerados, cambios de dirección y saltos) y analizar su comportamiento en diferentes contextos y bajo distintos factores.

Por último, la revisión realizada en la presente tesis solo ha podido identificar tres estudios donde jugadores profesionales de baloncesto (nivel 5) fueron monitorizados durante partidos amistosos de pre-temporada (Tabla 2). Además del bajo número de investigaciones con esta muestra tan exclusiva, los tres estudios encontrados solo utilizaron variables relacionadas con IMUs para comparar las demandas físicas entre entrenamientos y competición y entre posiciones de juego. En consecuencia, el presente doctorando reconoce una carencia de literatura científica para el análisis de las demandas físicas en jugadores profesionales de baloncesto durante competición oficial.

2.4. Comparativa entre entrenamiento y competición

Uno de los principales objetivos del análisis de las demandas físicas durante competición es el de optimizar el proceso de entrenamiento y, en consecuencia, el rendimiento en partidos. Para ello, es de vital importancia poder comparar las demandas físicas en sesiones de entrenamiento y partido, además de protocolizar muy bien todos los factores que definen las tareas de entrenamiento para permitir su réplica o modificación. En este sentido, O'Grady, Fox, Conte, Ferioli, Scanlan & Dalbo (2021) han publicado una serie de recomendaciones para mejorar la metodología de presentación de las tareas basadas en situaciones jugadas en baloncesto después de concluir que la mayoría de las tareas utilizadas están descritas de forma muy general y con poco detalle, lo que dificulta su comprensión e imposibilita su reproducción. Dichas recomendaciones se centran en parámetros como normativa (reglamento oficial FIBA o modificado), paradas (ejecución de tiros libres oficiales o saque de banda), situación numérica del equipo (del 1 contra 1 al 5 contra 5), área de juego (media pista o toda pista), dibujo ofensivo (acciones específicas de ataque como balón interior o bloqueo directo) y defensivo (defensa individual o zonal), tiempo de posesión (oficial o reducido), tiempo de juego y de descanso (partido simulado o series cortas), tarea táctica (sistemas de juego), intervención del equipo técnico (tipo y frecuencia de la retroalimentación) y arbitraje (cargo de responsabilidad y tipo de autoridad) (O'Grady et al., 2021).

Las investigaciones existentes en baloncesto que han comparado las demandas físicas durante sesiones de entrenamiento con los partidos regulados muestran conclusiones contradictorias sobre qué tipo de sesión es más demandante a nivel físico (Fox et al., 2020; Fox, Stanton & Scanlan, 2018; Montgomery et al., 2010; Reina et al., 2017; 2019b; y 2019c; Svilar et al., 2018). Por un lado, investigaciones recientes que han comparado las demandas físicas en entrenamiento basado en juegos reducidos (Fox et al., 2018) y 5 contra 5 con reglamento FIBA modificado para reducir pausas (Svilar et al., 2018) con partidos han mostrado valores promedios de variables derivadas de IMU superiores durante las sesiones preparatorias en jugadores semi-profesionales y profesionales de baloncesto, respectivamente. Cabe destacar que los dos estudios mencionados analizaron partidos amistosos de pre-temporada jugados en días consecutivos, los cuales podrían no replicar las demandas físicas durante partidos oficiales debido a que los entrenadores podrían considerar estas sesiones como preparatorias. Además, los jugadores podrían no llegar en las mejores condiciones posibles para mostrar su máximo rendimiento competitivo debido a la alta carga acumulada en este periodo de la temporada.

Aunque se ha demostrado que es posible superar las demandas físicas de competición durante tareas específicas mediante las variaciones en número de jugadores implicados, substituciones, espacio utilizado y control de las pausas, Svilar et al. (2018) no encontró demandas físicas superiores en la tarea de entrenamiento de 5 contra 5 siguiendo el reglamento oficial FIBA. En esta misma línea, investigaciones en jugadores Sub-19 de nivel 3 (Montgomery et al., 2010) y jugadoras sénior amateur de nivel 2 (Reina et al., 2017; Reina, García-Rubio, Feu, & Ibáñez, 2019) tampoco encontraron demandas físicas superiores en entrenamiento usando la tarea de 5 contra 5 simulado mediante valores promedios. Esta metodología podría explicar los resultados inferiores durante tareas de 5 contra 5 en entrenamiento debido a que los periodos de inactividad, como la instrucción e intervención del equipo técnico, podrían ser más frecuentes y prolongados que durante partidos (tiros libre y substituciones).

Además del uso de valores promedios y sus diversas limitaciones, Fox et al. (2020) también mostró valores superiores en las demandas físicas durante EME en competición oficial con diferencias entre moderadas y grandes (d de Cohen) con los entrenamientos en las múltiples ventanas temporales utilizadas (entre 30 s y 5 min). Sin embargo, cabe destacar que el estudio mencionado solo utilizó *player load* como variable de carga externa, hecho que podría limitar los resultados debido a la naturaleza del algoritmo indirecto utilizado. Asimismo, la «justificación del esfuerzo», o *effort rationale*, podría explicar la hipótesis más aceptada donde los mayores valores de demandas físicas tenderían a encontrarse en partidos oficiales de baloncesto debido a la inclusión de oponentes reales, aficionados y el consecuente aumento en motivación y concentración (Svilar et al., 2018).

En esta dirección, investigaciones previas en futbol profesional (Akenhead, Harley & Tweddle, 2016; Martín-García et al., 2018a) han utilizado la microtecnología para examinar las demandas físicas mediante valores promedios en entrenamiento y competición a lo largo de microciclos competitivos durante temporada. Siguiendo las recomendaciones de Akenhead et al. (2016), el presente doctorando encuentra muy interesante poder analizar las demandas físicas del baloncesto profesional en diferentes tipos de sesiones de entrenamiento tomando como referencia el número de días antes del siguiente partido (uno, dos, tres y cuatro días previos al partido) y su relación con los valores promedios y máximos (EME) durante competición oficial. Esta información permitiría a profesionales y analistas de baloncesto establecer relaciones entre la distribución de la carga de entrenamiento en los días previos a la competición y la posterior optimización del rendimiento individual y colectivo.

3. METODOLOGÍA

3.1. Diseños

Los cuatro estudios que componen la presente tesis fueron observacionales, descriptivos y retrospectivos. Sin embargo, los periodos de realización y los equipos monitorizados variaron entre los mismos.

3.1.1. Estudio 1

El equipo filial sénior del FCB de baloncesto fue monitorizado durante todos los 17 partidos oficiales de liga LEB Oro disputados como local durante la temporada 2018/2019 (setiembre-mayo). Las demandas físicas en valores promedios (tiempo total) durante competición fueron analizados mediante LPS y se comparó las diferencias entre cuartos y posiciones de juego en un total de 708 observaciones individuales.

3.1.2. Estudio 2

Los dos equipos profesionales de baloncesto del FCB fueron monitorizados durante un partido amistoso durante pre-temporada en setiembre de 2019. Las demandas físicas durante el partido fueron analizadas mediante LPS y se comparó la diferencia entre valores promedios y EME de 1 min por posiciones de juego en un total de 42 observaciones individuales.

3.1.3. Estudio 3

Cinco equipos masculinos de la cantera del FCB (Sub-12, Sub-14, Sub-16, Sub-18 y equipo filial sénior) fueron monitorizados durante ocho partidos oficiales de liga regular completados como local durante la temporada 2018/2019 (diciembre-mayo). Las demandas físicas durante competición fueron analizadas mediante LPS y se comparó la diferencia entre valores promedios y EME de 1 min por categorías de competición en un total de 344 observaciones individuales.

3.1.3. Estudio 4

El equipo filial sénior del FCB de baloncesto fue monitorizado durante todos los 39 microciclos de entrenamiento y los 17 partidos oficiales de liga LEB Oro disputados como local durante la temporada 2018/2019 (setiembre-mayo). Sin embargo, el presente estudio solo incluyó para el análisis de los EME de 1 min mediante LPS los nueve microciclos durante temporada (*in-season*) donde el equipo tuvo seis días entre partidos oficiales y completó un mínimo de cuatro sesiones de entrenamiento. En consecuencia, 428 observaciones individuales fueron analizadas para comparar las diferencias en las demandas físicas pico entre competición oficial y las diferentes sesiones de entrenamiento, considerando además las posiciones de los jugadores en juego.

3.2. Participantes

Un total de 88 jugadores (media y desviación estándar, edad: 17,8 ± 5,2 años; altura: 191,9 ± 14,0 cm; y masa corporal: 82,7 ± 18,6 kg) divididos en siete equipos diferentes de la sección de baloncesto del FCB fueron monitorizados en entrenamientos y partidos durante las temporadas 2018/2019 y 2019/2020 (Tabla 5).

Tabla 5. Descripción antropométrica de los jugadores analizados

Equipos	Nivel	n	Edad (años)	Altura (cm)	Masa corporal (kg)
1er equipo	5	11	28,3 ± 3,7	203,5 ± 8,9	100,9 ± 13,4
2º equipo (LEB Oro)	5	13	19,8 ± 1,7	199,8 ± 8,7	91,8 ± 15,9
2º equipo (LEB Plata)	5	12	19,3 ± 1,2	198,9 ± 9,7	91,6 ± 14,2
Sub-18	3	12	16,8 ± 0,6	198,5 ± 9,3	88,7 ± 13,7
Sub-16	1	16	15,0 ± 0,5	194,7 ± 7,8	80,1 ± 10,5
Sub-14	1	14	13,0 ± 0,4	175,3 ± 6,4	60,9 ± 8,9
Sub-12	1	11	11,2 ± 0,3	167,0 ± 8,0	56,9 ± 11,9

Los equipos de cantera Sub-12, Sub-14, Sub-16 y Sub-18 compitieron al máximo nivel autonómico (Cataluña) de sus respectivas categorías. Además, el equipo filial sénior (Barça B) compitió en la Liga LEB Oro (2ª división española) durante la temporada 2018/2019 y en la Liga LEB Plata (3ª división española) durante la temporada 2019/2020.

Por su parte, el primer equipo de baloncesto del FCB combinó su participación durante ambas temporadas en la Liga Endesa (ACB, 1ª división española) y la Euroliga (1ª división europea). Todos los estudios se ajustaron a las recomendaciones de la Declaración de Helsinki (Harriss & Atkinson, 2015). Además, la autorización del comité de ética no fue requerida debido a que los datos fueron obtenidos durante la monitorización diaria de todos los jugadores durante entrenamientos y partidos (Winter & Maughan, 2009). No obstante, todos los jugadores mayores de edad y los representantes legales de los jugadores menores de edad proporcionaron su consentimiento por escrito después que se les explicase el objetivo de la investigación junto a sus protocolos y requerimientos.

3.2.1. Estudios 1 y 4

Los 13 participantes fueron jugadores profesionales de baloncesto (promedios ± SD, edad: 19,8 ± 1,7 años; altura: 199,9 ± 8,2 cm; and masa corporal: 91,8 ± 15,9 kg), los cuales compitieron en la liga LEB Oro durante la temporada 2018/2019. Los jugadores de este equipo completaban durante la temporada regular cinco sesiones de entrenamiento grupal a la semana de entre 90 y 150 min por las mañanas, además de sesiones individuales de técnica individual o físico por las tardes. Aunque el equipo tuvo dos jornadas intersemanales, la normalidad del calendario era jugar un partido a la semana (entre viernes y domingo). Los jugadores competían organizados en tres posiciones de juego que se mantuvieron estables durante la temporada: exteriores (n = 7), aleros/ala-pívots (n = 3) y pívots (n = 3).

3.2.2. Estudio 2

Los 21 participantes pertenecían a dos equipos de baloncesto profesional diferentes (edad: 27,9 ± 3,9 años; altura: 200,1 ± 11,3 cm; masa corporal: 94,6 kg ± 11,8), los cuales fueron monitorizados durante un partido amistoso durante la temporada 2019/2020. Los jugadores del 1er equipo y 2º equipo del FCB jugaron con los equipos que estaban acostumbrados a entrenar y competir en su habitual posición de juego (11 exteriores, 5 aleros/ala-pívots y 5 pívots).

3.2.3. Estudio 3

Los 66 participantes en este estudio eran jugadores de baloncesto que pertenecían a cinco equipos diferentes de la cantera de baloncesto formativo del FCB (mini o Sub-12, infantil o Sub-14, cadete o Sub-16 y junior o Sub-18, y equipo filial sénior). A parte del equipo sénior que compitió en LEB Oro, los equipos Sub-18, Sub-16 y Sub-14 compitieron siguiendo el reglamento FIBA en la máxima división autonómica (Cataluña). Por su lado, el equipo Sub-12 compitió en la categoría Sub-13, una liga que seguía un reglamento FIBA modificado. Todos los equipos siguieron la metodología de trabajo de entrenamiento estructurado del FCB y acostumbraban a jugar un partido a la semana durante la temporada regular.

3.3. Procedimientos

Todas las sesiones de entrenamiento y partido fueron realizadas en la cancha de baloncesto de la «Ciudad Deportiva Joan Gamper» bajo condiciones ambientas similares (entre 20 y 22ºC). Los jugadores que se lesionaron durante las sesiones analizadas, no pudieron acabar los entrenamientos por razones diversas o jugaron menos de 10 min de tiempo total en competición fueron excluidos de los análisis. Además, los jugadores pudieron beber agua *ad libitum* en periodos de recuperación. Todos los equipos monitorizado pertenecían al mismo club y se prepararon siguiendo la metodología del «entrenamiento estructurado» propia del FCB (Seirul·lo, 2017; Tarragó et al., 2019).

Los datos para la cuantificación de las demandas físicas en jugadores de baloncesto fueron obtenidos mediante el sistema EPTS (*Electronic Perfomance and Tracking System*) WIMU PRO™ (RealTrack Systems S.L., Almería, España). Antes de empezar cualquier sesión, el preparador físico encargado de la monitorización de los jugadores (licenciado en ciencias de la actividad física y del deporte y *Certified Strength and Conditioning Specialist*, CSCS-NSCA) comprobó rigurosamente que los dispositivos inerciales estaban cargados al 100% y tenían espacio de almacenamiento suficiente, así como el correcto funcionamiento de las seis antenas de banda ultra-ancha distribuidas por la instalación deportiva. A falta de 15 y 45 min para empezar los entrenamientos o partidos, respectivamente, el preparador físico correspondiente ayudaba a los jugadores a colocar el dispositivo inercial individual (81x45x16 mm, 70 gr, Figura 5) en el centro de la parte alta de la espalda en un chaleco ajustado (IMAX, Lleida, España). Después de un periodo de familiarización de dos semanas donde los jugadores probaron diferentes tallas de chaleco y entrenaron y compitieron con chaleco y dispositivo, cada jugador utilizó el mismo material durante todo el proceso de recogida de datos para optimizar su validez y fiabilidad. Finalizada la sesión, el preparador físico se encargaba de recoger los dispositivos, colocarlos debidamente en la maleta correspondiente y proceder con la descarga y análisis de datos mediante el programa específico del sistema (SPRO™, versión 959, RealTrack Systems, Almería, España).

Figura 5. *Equipamiento del sistema de monitorización WIMU PRO™ (RealTrack Systems S.L., Almería, España)*

Específicamente, la tecnología WIMU PRO™ incluye LPS de banda ultra ancha (frecuencia de muestreo de 18 Hz), GPS (frecuencia de muestreo de 10 Hz), cuatro acelerómetros 3D (frecuencia de muestreo de 100 Hz), giroscopio (8000º/s *full-scale output range*, frecuencia de muestreo de 100 Hz), y manómetro 3D (frecuencia de muestreo de 100 Hz). Para el deporte del baloncesto, el LPS utiliza seis antenas de banda ultra ancha colocadas en posición rectangular fuera de los límites de la pista de baloncesto (Figura 6). Este LPS funciona mediante triangulaciones donde las seis antenas envían una señal a las unidades cada 50 ms. Usando una antena de referencia, cada dispositivo calcula el tiempo necesario para recibir la señal y derivar la posición de la unidad (coordenadas X y Y). Cabe destacar que WIMU PRO™ ha demostrado tener buena precisión y fiabilidad entre y intra dispositivos para posicionamientos de banda ultra ancha (Bastida-Castillo, Gómez Carmona, De la Cruz Sánchez, & Pino Ortega, 2018; Bastida-Castillo et al., 2019b; Bastida-Castillo, Gómez-Carmona, Sánchez, & Pino-Ortega, 2019a). Además del sistema LPS, WIMU PRO™ también incluye dispositivos inerciales individuales, los cuales contienen un micro-procesador de un gigahercio, memoria flash de 8GB y un interfaz USB de alta velocidad para grabar, almacenar y cargar datos.

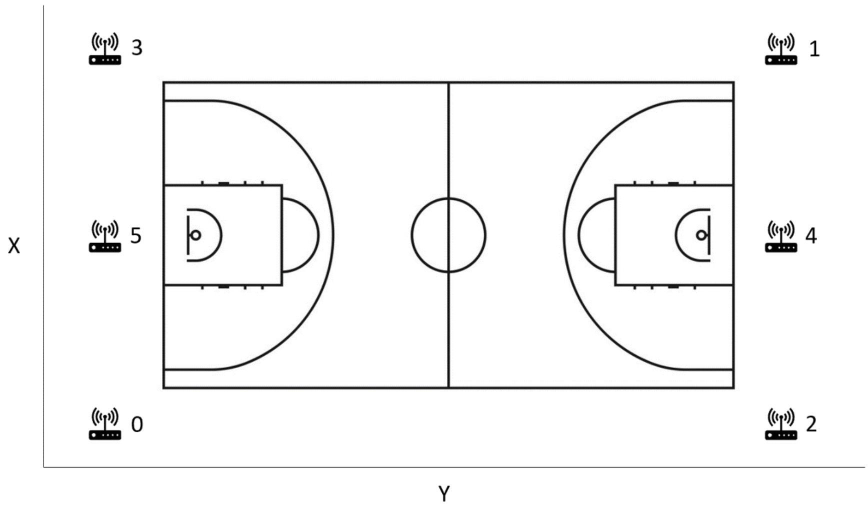

Figura 6. *Sistema local de posicionamiento de banda ultra ancha en pista de baloncesto. Los números muestran la disposición de las antenas en cm (x es ancho de pista; y = largada de pista; y z = altura de las antenas): 0 es x = 0, y = 0, z = 600; 1 es x = 2924, y = 5208, z = 600; 2 es x = 0, y = 5208, z = 600; 3 es x = 2928, y = 7, z = 600; 4 es x = 1469, y = 5207, z = 600; and 5 es x = 1456, y = 2, z = 600.*

3.4. Variables

La Tabla 6 muestra un total de 11 variables utilizadas para el análisis de las demandas físicas en baloncesto durante competición incluidas en la siguiente tesis, además del tipo de tecnología que utilizan, su descripción y en los estudios específicos que fueron empleadas. Para las variables registradas con el LPS, cabe destacar que la velocidad máxima, la distancia total y la carrera de alta intensidad (distancia y número acciones >18 km·h^{-1}) fueron medidas mediante diferenciación posicional (cambio de localización en cada señal), mientras que las variables de aceleración y desaceleración fueron calculadas mediante doble diferenciación (Malone, Lovell, Varley, & Coutts, 2017).

***Tabla 6.** Descripción de las variables utilizadas para el análisis de las demandas físicas*

Variable	Códigos	Sistema	Descripción	Estudios
Velocidad máxima	PV	LPS	Velocidad máxima (km·h^{-1})	1
Distancia total	TDC	LPS	Distancia recorrida > 0 km·h^{-1}	1, 2, 3, 4
Carrera de alta intensidad	D18	LPS	Distancia recorrida > 18 km·h^{-1}	1, 2, 3, 4
		LPS	Número de acciones > 18 km·h^{-1}	2
Aceleraciones	D.ACC	LPS	Distancia recorrida en aceleraciones > 2 m·s^{-2}	2, 4
	N.ACC	LPS	Número de aceleraciones > 2 m·s^{-2}	1, 2, 3, 4
Desaceleraciones	D.DEC	LPS	Distancia recorrida en desaceleraciones > 2 m·s^{-2}	2, 4
	N.DEC	LPS	Número de desaceleraciones > 2 m·s^{-2}	1, 2, 3, 4
Carga externa total (*player load*)	PL	IMU	Magnitud vectorial derivada del acelerómetro triaxial expresada en unidades arbitrarias	1
Saltos	JUM	IMU	Número de saltos > 3G	1
Impactos	IMP	IMU	Número de impactos > 8G	1

Nota: LPS = Sistemas de posicionamiento local; IMU = Unidades de medición inercial.

Respecto a la variable de carga externa total, también conocida como *player load,* entendida como la magnitud del cambio en aceleración expresada en unidades arbitrarias, ha sido definida y calculada de diferentes maneras des de su aparición en 2010 (Montgomery et al., 2010), limitando así su capacidad ser entendida, aplicada y comparada (Bredt, Chagas, Peixoto, Menzel, & Andrade, 2020). La figura 4 muestra la fórmula inicial de *player load* publicada por la empresa tecnológica Catapult Sports (Boyd et al., 2011) y definida como un vector modificado de magnitud expresado con la raíz cuadrada de la suma de las unidades de cambio de aceleración del microsensor en sus tres ejes (vertical, anteroposterior y lateral). Además del cálculo de *player load* clásico, WIMU PRO™ añade el cálculo de la integral y la división del periodo (100) entre 1000 para pasar de milisegundos a segundos.

$$PL = \sqrt{\frac{(\mathrm{X} - \mathrm{XAnt})^2 + (\mathrm{Y} - \mathrm{YAnt})^2 + (\mathrm{Z} - \mathrm{ZAnt})^2}{100}}$$

Figura 4. *Ecuación para el cálculo de la carga externa total (player load).*

Para el análisis de los promedios por jugador durante competición, los valores absolutos de cada variable fueron relativizados por el tiempo total que los jugadores permanecieron en pista, incluyendo todos los parones del juego como tiros libres y tiempos muertos y solo excluyendo los periodos entre cuartos (1,5 min entre 1er y 2º cuarto y entre 3er y 4º cuarto; y 15 min entre 2º y 3er cuarto) (Vázquez-Guerrero, Fernández-Valdés, Gonçalves & Sampaio, 2019a.; Vázquez-Guerrero et al., 2019b; Vázquez-Guerrero et al., 2019c). Además del estudio de los valores medios, el valor más alto por jugador y variable durante la ventana temporal de 1 min fue analizado mediante el método del promedio móvil, también conocido como *rolling average* o *moving average* (Whitehead et al., 2018), para identificar los EME.

Con un muestreo de 18 Hz, el programa específico SPRO™ identificó 1080 datos consecutivos (18 muestras durante 60 s) para el cálculo de los EME. La elección de la ventana temporal de 1 min se debió a dos razones fundamentales: 1) la naturaleza intrínseca intermitente del baloncesto permite solo un 15% de acciones continuadas (sin interrupciones) superiores a 1 min (Salazar & Castellano, 2020), por lo que el presente doctorando consideró esta ventana temporal como óptima para el análisis de los EME; y 2) la posibilidad de comparativa con los valores medios durante competición. En consecuencia, los valores de las variables referentes a distancia fueron expresadas en $m \cdot min^{-1}$, mientras que las variables referentes a número de acciones fueron expresadas en $n \cdot min^{-1}$ tanto para el estudio de valores medios como de los EME.

3.5. Análisis de datos

A partir de las medias y desviaciones standard para la descripción de las variables físicas, los análisis estadísticos para llevar a cabo la comparativa entre las variables independientes incluyeron el tamaño del efecto (*d* de Cohen) como diferencia de medias estandarizadas y su intervalo de confianza del 90% (Cohen, 1988). Los umbrales para interpretar estas diferencias fueron <0.20, triviales; 0.20-0.59, pequeñas; 0.60-1.19, moderadas; 1.20-1.00, grandes; y <2.0, muy grandes (Hopkins, Marshall, Batterham & Hanin, 2009). Además del tamaño del efecto, cada estudio incluyó análisis estadísticos tradicionales basados en las diferencias significativas, todas ellas fijadas en $p<0.05$. De manera particular cada uno de los estudios incluyó una analítica específica.

3.5.1. Estudio 1

Con el objetivo de realizar una primera inspección visual de los datos se utilizó la matriz de la correlación de Pearson con las ocho variables utilizadas. Las diferencias entre cuartos y posiciones fueron analizadas usando el modelo mixto lineal, donde las variables de las demandas físicas fueron fijadas como variables dependientes, los cuartos (primero, segundo, tercero y cuarto) y las posiciones (exteriores, ala-pívots y pívots) fueron incluidos como efectos fijos (*fixed effects*) y los jugadores fueron considerados como efectos aleatorios (*random effects*). Estos análisis fueron realizados mediante *Statistical Package for Social Sciences* (versión 25 para Windows; SPSS, Chicago, IL, USA) y R (*The R Foundation para statistical Computing*, Vienna, Austria), R versión 3.3.2 (*R Core team*, 2016) con el paquete nlme y lmerTest.

3.5.2. Estudio 2

Las variables que mostraron una distribución normal en la prueba de Shapiro-Wilk fueron analizadas mediante la prueba de muestras independientes t-test. Por el contrario, la diferencia entre los promedios y los EME en las tres variables dependientes que no presentaron una distribución normal fueron calculados mediante la prueba no paramétrica de Mann-Whitney U. Todos los análisis fueron realizados mediante *Statistical Package for Social Sciences* (version 25 para Windows; SPSS, Chicago, IL, USA).

3.5.3. Estudio 3

La prueba de muestras independientes t-test fue utilizada para comparar los premios con los EME de 1 min. Además, las diferencias entre categorías fueron calculadas mediante el análisis de la varianza de un factor y las comparaciones por parejas *holm post-hoc*. Se utilizó el paquete estadístico de R Studio (*The R Foundation for Statistical Computing*, Vienna, Austria) para realizar estas pruebas estadísticas.

3.5.4. Estudio 4

Las diferencias entre los diferentes tipos de sesiones y posiciones de juego fueron calculadas mediante el análisis de la varianza para medidas repetidas y las pruebas post-hoc de Bonferroni. Los análisis estadísticos fueron realizados mediante el programa JASP v0.9.2 (*University of Amsterdam*, https://jasp-stats.org/).

4. OBJETIVOS E HIPÓTESIS

El objetivo principal de este proyecto fue describir las demandas físicas del baloncesto durante competición oficial en distintas categorías mediante el uso de IMUs y LPS, atendiéndose de manera específica a los EME. El objetivo secundario fue comparar los EME durante sesiones de entrenamiento y partido. Las aportaciones de este trabajo permitirán establecer estrategias para la optimización del proceso de entrenamiento y, en consecuencia, la optimización del rendimiento individual y colectivo en competición. Los dos objetivos generales serán abordados a partir de cuatro estudios específicos.

4.1. Estudio 1

- **Objetivo específico:** describir y comparar las demandas físicas a partir de los promedios entre cuartos y posiciones de juego en jugadores profesionales de baloncesto durante la competición oficial de liga regular.
- **Hipótesis:** la hipótesis de partida es que las demandas físicas en el último cuarto tienden a aumentar respecto al inicio de partido debido al incremento de competitividad en los minutos finales. Asimismo, la hipótesis para la comparativa entre posiciones de juego (exteriores o *guards*, aleros/ala-pívots o *forwards* y pívots o *centers*), es que se encontrarán múltiples diferencias significativas.

  Los resultados de esta investigación podrían ayudar a los entrenadores a reforzar metodologías basadas en la individuación y plantearse la afectación real de la aparición de fatiga al final de los partidos de baloncesto.

- **Publicación:** García, F., Vázquez-Guerrero, J., Castellano, J., Casals, M., & Schelling, X. (2020). Differences in physical demands between game quarters and playing positions on professional basketball players during official competition. *Journal of Sports Science and Medicine*, 19(2), 256–263.

4.2. Estudio 2

- **Objetivo específico:** comparar el análisis de las demandas físicas durante competición en jugadores profesionales de baloncesto mediante el método tradicional de promedios con los EME de un minuto.
- **Hipótesis:** la hipótesis de partida es que se espera que se encontrarán grandes diferencias entre los promedios y los EME de un minuto.

  Esta información puede ser de gran ayuda para entrenadores, preparadores físicos y readaptadores para establecer el límite superior de exigencia que las diferentes posiciones específicas del baloncesto se encontrarán en competición.
- **Publicación:** Vázquez-Guerrero, J., & García, F. (2020). Is it enough to use the traditional approach based on average values for basketball physical performance analysis? *European Journal of Sport Science*, 1–18. https://doi.org/10.1080/17461391.2020.1838618

4.3. Estudio 3

- **Objetivo específico:** describir y comparar las demandas físicas entre cinco categorías de baloncesto formativo (Sub-12, Sub-14, Sub-16, Sub-18 y Sénior) mediante el uso de promedios y de EME de un minuto durante competición oficial de liga regular.

- **Hipótesis:** la hipótesis de partida es que los EME serán significativamente más altos que los promedios, se espera que las demandas físicas tiendan a incrementarse progresivamente con la edad de los jugadores.

  Esta investigación puede proveer información práctica a los entrenadores de las distintas categorías de baloncesto para estableces límites medios y máximos específicos para los jugadores que entrenan y poder así optimizar el proceso de entrenamiento y competición.

- **Publicación:** García, F., Castellano, J., Reche, X., & Vázquez-Guerrero, J. (2021). Average game physical demands and the most demanding scenarios of basketball competition in various age groups. *Journal of Human Kinetics*.

4.4. Estudio 4

- **Objetivo específico:** comparar las demandas físicas en diferentes tipos de sesiones de entrenamiento (uno, dos, tres y cuatros días antes de partido) y partidos oficiales de liga en jugadores profesionales de baloncesto mediante el uso de los EME de 1 minuto.

- **Hipótesis:** la hipótesis es que la mayoría de las variables analizadas presenten valores máximos superiores en sesiones de entrenamiento alejadas a la competición, como por ejemplo tres y cuatro días antes del partido, en comparación a la propia competición oficial de liga.

  Además de la posible individualización del entrenamiento debido a la diferenciación de las tres principales posiciones de juego, el conocimiento entre la variación de los valores máximos entre entrenamientos durante temporada regular y competición oficial puede optimizar la preparación de los deportistas durante microciclos competitivos.

- **Publicación:** García, F., Schelling, X., Castellano, J., Pla, F., & Vázquez-Guerrero, J. (2021). Comparison of the most demanding scenarios during different in-season training sessions and official matches in professional basketball players. *Biology of Sport*, 39(2). https://doi.org/10.5114/biolsport.2022.104064.

5. RESULTADOS Y DISCUSIÓN

5.1. Estudio 1

El presente estudio demostró diferencias significativas entre exteriores y pívots en las variables de velocidad máxima, distancia total y saltos. Para ser más precisos, los pívots consiguieron los valores más reducidos en distancia total, dato que puede ser justificado por el hábito que tiene esta posición de permanecer cerca de la zona de tres segundos en jugadas posicionales debido a razones tácticas y estratégicas. En esta misma línea, la posición de pívot también consiguió el mayor número de saltos, pudiendo ser debido a su responsabilidad de taponar y rebotear tiros cerca de la canasta.

Además de las diferencias entre posiciones, el 4º período mostró valores significativamente reducidos en comparación al 1r cuarto en variables como distancia total, carga externa total, distancia en carrera de alta intensidad, y número de aceleraciones, desaceleraciones y saltos (Figura 7). Es importante destacar que la duración total media de cada periodo fue diferente: 17,5 ± 1,4 min en el 1r cuarto; 22,9 ± 2,3 min en el 2º cuarto; 20,1 ± 2,1 min en el tercer cuarto; y 23,9 ± 2,3, min en el 4º cuarto. Debido a que investigaciones previas (Oba & Okuda, 2011; Scanlan, Tucker, Dascombe & Berkelmans, 2015) no han encontrado diferencias en las demandas físicas entre cuartos utilizando el tiempo efectivo de juego para normalizar los datos absolutos, la utilización del tiempo total junto a la posible disminución del ritmo de partido en el último periodo debido a razones tácticas podrían explicar las diferencias encontradas.

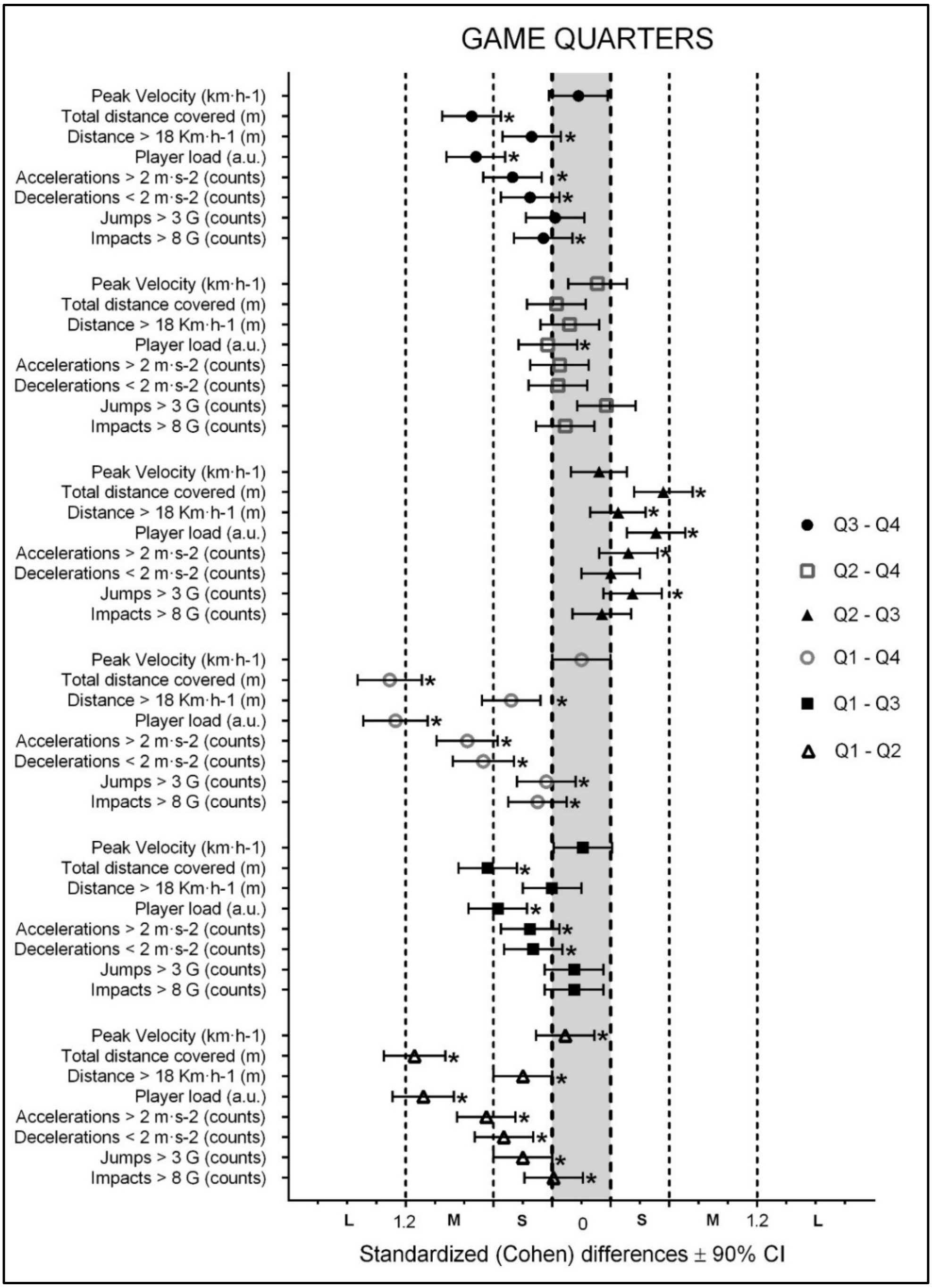

Figura 7. *Diferencias estandarizadas (d de Cohen) y sus respectivos intervalos de confianza del 90% (IC) entre cuartos. Las diferencias significativas están mostradas con * a la derecha del IC. 1Q = 1r cuarto; 2Q = 2º cuarto; 3Q = 3r cuarto; 4Q = 4º cuarto; L = Tamaño del efecto grande; M = Tamaño del efecto moderado; S = Tamaño del efecto pequeño*

5.2. Estudio 2

El resultado principal de este estudio mostró aumentos muy grandes entre la utilización de los valores medios y los EME de 1 minuto para el análisis de las demandas físicas durante competición. En concreto, se observó un aumento del 113% en distancia total, 686% en distancia en carrera de alta intensidad, y 252% y 291% en el número de aceleraciones y desaceleraciones respectivamente (Tabla 7). Estas diferencias tan exageradas entre los dos métodos se deben a la eliminación del tiempo acumulado sin actividad y la detección del periodo de máxima exigencia condicional durante el partido.

Tabla 7. *Promedios (±SD) en las siete variables seleccionadas para valores medios y los escenarios de máxima exigencia de 1 min*

Variables	Posiciones	Promedios	EME 1 MIN	Dif %
Distancia total ($m{\cdot}min^{-1}$)	Exteriores	66,9 ± 9,0 (52,7 – 78,2)	144,3 ± 10,8 (128,2 – 161,6)	115,7
	Alero/ Ala-pívot	70,2 ± 6,2 (61,2 – 75,6)	142,8 ± 10,1 (133,2 – 154,9)	103,4
	Pívots	62,7 ± 6,7 (52,2 – 71,1)	131,4 ± 7,3 (122,0 – 142,1)	109,6
	Todos los jugadores	66,3 ± 8,0 (52,2 – 78,2)	141,3 ± 11,0 (122,0 – 161,6)	113,1
Carrera en alta intensidad (distancia; $m{\cdot}min^{-1}$)	Exteriores	3,1 ± 1,6 (0,8 – 6,4)	29,4 ± 4,7* (16,5 – 38,2)	848,4
	Alero/ Ala-pívot	3,7 ± 1,6 (1,4 – 5,0)	25,3 ± 7,7 (17,7 – 35,6)	583,8
	Pívots	3,2 ± 0,9 (2,0 – 4,5)	19,3 ± 4,4** (15,2 – 24,4)	503,1
	Todos los jugadores	3,23 ± 1,4 (0,8 – 6,4)	25,4 ± 6,8 (15,2 – 38,2)	686,4
Carrera en alta intensidad (número; $n{\cdot}min^{-1}$)	Exteriores	0,4 ± 0,2 (0,1 – 0,8)	3,2 ± 0,9 (2,0 – 5,0)	700,0
	Alero/ Ala-pívot	0,4 ± 0,1 (0,3 – 0,6)	2,4 ± 0,6 (2,0 – 3,0)	500,0
	Pívots	0,3 ± 0,1 (0,1 – 0,5)	2,4 ± 0,9 (2,0 – 4,0)	700,0
	Todos los jugadores	0,4 ± 0,2 (0,1 – 0,8)	2,9 ± 0,9 (2,0 – 5,0)	652,0

Tabla 7. Promedios (±SD) en las siete variables seleccionadas para valores medios y los escenarios de máxima exigencia de 1 min. (continuación)

Variables	Posiciones	Promedios	EME 1 MIN	Dif %
Aceleraciones (distancia; m·min^{-1})	Exteriores	13,1 ± 4,2 (8,7 – 21,9)	50,5 ± 10,3 (32,5 – 62,5)	285,5
	Alero/ Ala-pívot	11,6 ± 0,9 (10,1 – 12,4)	53,5 ± 14,5 (40,1 – 74,5)	361,2
	Pívots	9,7 ± 3,8 (3,1 – 14,0)	43,3 ± 9,0 31,0 – 54,6)	246,4
	Todos los jugadores	11,8 ± 3,8 (3,1 – 21,9)	49,9 ± 11,1 (31,0 – 74,5)	322,9
Desaceleraciones (distancia; m·min^{-1})	Exteriores	9,9 ± 3,2 (5,6 – 15,6)	44,7 ± 5,9 (34,0 – 53,4)	351,5
	Alero/Ala-pívot	9,4 ± 2,9 (8,0 – 10,6)	42,9 ± 7,9 (33,4 – 49,2)	356,4
	Pívots	9,0 ± 3,1 (3,1 – 12,3)	41,8 ± 8,4 (31,3 – 54,8)	264,4
	Todos los jugadores	9,5 ± 2,8 (3,1 – 15,6)	43,4 ± 6,4 (31,3 – 54,8)	356,8
Aceleraciones (número; n·min^{-1})	Exteriores	2,7 ± 1,2 (1,6 – 5,9)	8,4 ± 1,2 (7,0 – 13,0)	211,1
	Alero/Ala-pívot	2,6 ± 0,2 (2,1 – 2,7)	9,0 ± 0,7 (8,0 – 10,0)	246,6
	Pívots	2,1 ± 0,8 (0,8 – 3,1)	8,6 ± 2,2 (6,0 – 12,0)	309,5
	Todos los jugadores	2,5 ± 1,0 (0,8 – 5,9)	8,8 ± 1,6 (6,0 – 13,0)	252,0
Desaceleraciones (número; n·min^{-1})	Exteriores	2,6 ± 1,0 (1,03 – 4,7)	8,2 ± 1,6 (5,0 – 12,0)	215,4
	Alero/Ala-pívot	2,1 ± 0,3 (1,7 – 2,3)	7,8 ± 1,3 (6,0 – 9,0)	271,4
	Pívots	2,1 ± 0,7 (0,8 – 3,1)	8,0 ± 1,2 (7,0 – 10,0)	281,0
	Todos los jugadores	2,1 ± 0,8 (0,8 – 4,7)	8,2 ± 1,6 (5,0 – 12,0)	290,5

Nota: EME = Escenario de Máxima Exigencia. DIF % = % de diferencia. Los promedios mostraron diferencias significativas (SD) con todos los valores de EME para todas las posiciones. Además, las diferencias significativas entre posiciones de juego se mostraron así: * SD con pívots y ** SD con exteriores.

5.3. Estudio 3

En la misma línea que en el estudio 2, se detectaron diferencias significativas entre el método de análisis de valores medios y los EME de 1 minuto en las variables de distancia total, distancia en carrera de alta intensidad, y en el número de aceleraciones y desaceleraciones (58,4 - 639,2%).

Además de las diferencias entre técnicas (Figura 8), las distintas categorías también mostraron variaciones entre ellas. Por ejemplo, el presente estudio observó que los valores medios en distancia total fueron significativamente superiores en la categoría con jugadores más jóvenes (Sub-12). Sin embargo, esta misma variable presentó resultados significativamente inferiores en la categoría con jugadores más mayores (sénior). Estos resultados pueden ser explicados debido a un mayor tiempo total de partido en baloncesto sénior, así como al hecho que jugadores con mayor experiencia tienden a interpretar mejor el juego y a optimizar la toma de decisiones (Sampaio et al., 2015).

Al contrario que los valores medios en distancia total, los resultados inferiores en los EME en esta variable fueron observados en la categoría Sub-12, lo que podría ser justificado debido a factores fisiológicos (Papaiakovou et al., 2009). Estos resultados opuestos entre métodos para una misma variable (distancia total) y una misma categoría (Sub-12) muestran la importancia de la utilización de los EME para la descripción de la competición.

El presente estudio también demostró resultados inferiores en distancia en carrera de alta intensidad en la categoría Sub-14 en comparación al resto de categorías superiores. Estos resultados van en concordancia con Mujica et al. (2009), el cual demostró diferencias significativas en el rendimiento del esprín entre las categorías Sub-14 y Sub-15 de futbol debido, probablemente, al estado de maduración física (Mujika, Spencer, Santisteban, Goiriena & Bishop, 2009). Por último, las variables de número de aceleraciones y desaceleraciones no mostraron gran variabilidad entre categorías, hecho que permite el planteamiento si el límite de 2 m·s^{-2} utilizado es suficiente para considerar acciones de alta intensidad.

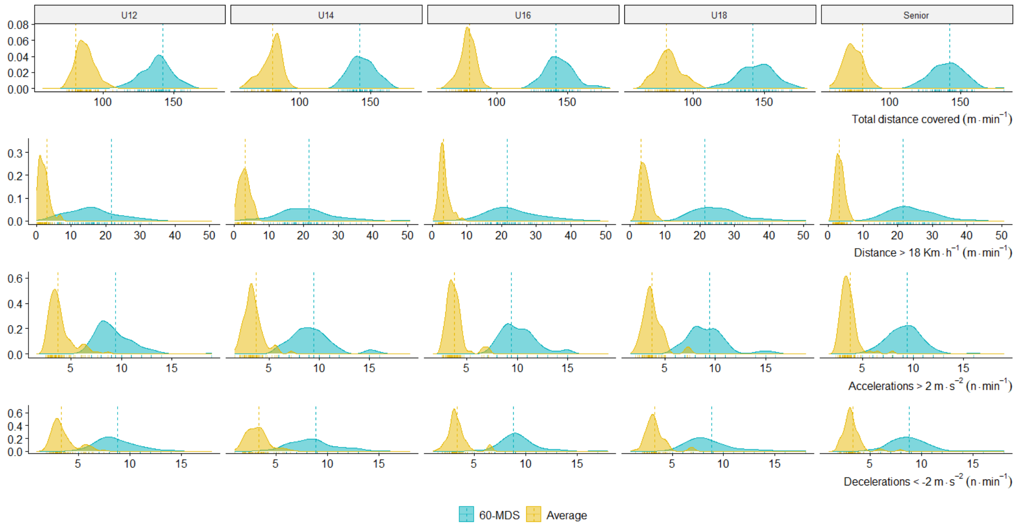

Figura 8. Gráfico de densidad entre las cinco categorías. «Average» son los valores medios, «60-MDS» son los escenarios de máxima exigencia de un minuto, U12 es Sub-12, U14 es Sub-14, U16 es Sub-16 y U18 es Sub-18. Los valores medios y los escenarios de máxima exigencia mostraron diferencias significativas en todas las variables entre todas las categorías.

5.4. Estudio 4

La comparativa entre EME de entrenamiento y partido demostró que en la mayoría de las variables analizadas los EME durante competición oficial fueron superiores (6,2% - 35,4%) a los valores durante los diferentes tipos de entrenamiento (Figura 9). Aunque en las sesiones MD-4 y MD-3 la propuesta de entrenamiento ya intentó superar los límites superiores de intensidad del partido, la «justificación del esfuerzo» indica que las demandas físicas tienden a conseguir los valores máximos durante la competición oficial debido a la inclusión de oposición real, espectadores y sus consecuente aumente en concentración y motivación (Svilar et al., 2018).

La única variable que mostró valores superiores en los EME durante MD-4 y MD-3 con la competición oficial fue la distancia en carrera de alta intensidad, lo que indica que en estas sesiones se incluyó algún ejercicio donde los jugadores corrían la pista de lado a lado a intensidades altas durante periodos superiores a un minuto (ejemplo: 3c3c3c3 continuo). Al contrario que las sesiones de principios de semana, los entrenamientos MD-2 y MD-1 presentaron una reducción muy significativa en los EME alcanzados en comparación a los valores de partido. Este efecto de sobrecompensación previo a la competición, también conocido como *tapering* en la literatura anglosajona, también ha sido descrito en múltiples deportes de equipo y tiene el objetivo principal de reducir las demandas físicas los días previos a la competición para permitir suficiente tiempo de recuperación a los deportistas y poder llegar en un estado de forma óptimo.

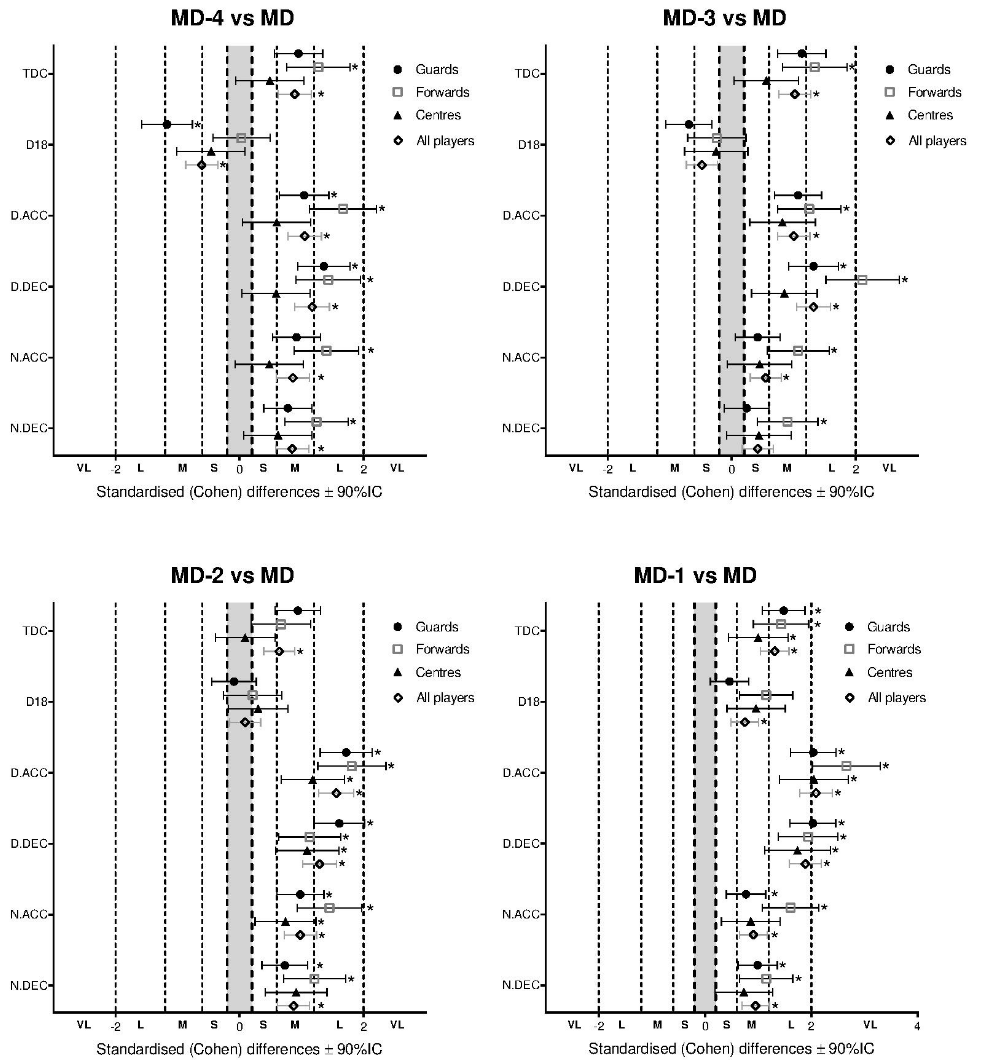

***Figura 9.** Diferencias estandarizadas (d de Cohen) y sus respectivos intervalos de confianza del 90% (IC) entre entrenamiento y partidos por posiciones. Las diferencias significativas están mostradas con * a la derecha del IC. TDC es distancia total; D18 es distancia en carrera de alta intensidad; D.ACC es distancia en aceleración; D.DEC es distancia en desaceleración; N.ACC es número de aceleraciones; N.DEC es número de desaceleraciones; L = Tamaño del efecto grande; M = Tamaño del efecto moderado; S = Tamaño del efecto pequeño*

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II. CONCLUSIONES

7. CONCLUSIONES

7.1. Estudio 1

Las demandas físicas de jugadores profesionales de baloncesto durante competición oficial presentan múltiples diferencias significativas entre cuartos y posiciones de juego.

Aunque la fatiga acumulada por jugadores con una carga competitiva muy elevada podría tener un impacto negativo en algunos de los parámetros físicos en el cuarto periodo, parece ser que los principios tácticos, incluyendo un elevado número de parones y un consecuente aumento de la duración del periodo, podrían justificar mejor el descenso en los resultados físicos encontrados en el último periodo de partido.

Además, la comprensión de las diferentes necesidades físicas en las distintas posiciones de juego podría reforzar intervenciones de entrenamiento basadas en la individualización.

7.2. Estudio 2

El método tradicional basado en valores promedios infraestima las demandas físicas pico en la ventana temporal de 1 min durante competición en jugadores profesionales de baloncesto. Por esta razón, se recomienda complementar el enfoque de valores promedios con el análisis de los EME para entender mejor las demandas físicas en baloncesto.

Además, las múltiples diferencias entre posiciones de juegos también deberían ser consideradas para optimizar la preparación del equipo en función de las demandas específicas de cada posición.

7.3. Estudio 3

Las demandas físicas durante competición basadas en valores promedios infraestima los valores obtenidos en los EME en jugadores de baloncesto de hasta cinco categorías diferentes (Sub-12, Sub-14, Sub-16, Sub-18 y séniors). Debido a que el enfoque tradicional basado en valores promedios parece ser insuficiente para la prescripción del proceso de entrenamiento, se recomienda usar el promedio móvil (*rolling average*) para describir los EME durante la competición. De esta manera, entrenadores y preparadores físicos podrían establecer el límite superior de cada parámetro físico y prescribir el entrenamiento en consecuencia para optimizar el rendimiento durante competición.

Además, las demandas físicas muestran múltiples diferencias significativas entre las cinco categorías de edad de baloncesto investigadas, con especial atención a distancia total recorrida y carrera a alta intensidad (*high-speed running*).

7.4. Estudio 4

La mayoría de parámetros físicos examinados durante los EME fueron mayores durante partidos oficiales que en sesiones de entrenamiento durante el microciclo estructurado durante temporada en jugadores profesionales de baloncesto. El conocimiento de los EME durante tipos de sesiones diferentes (de cuatro a un día antes de partido) podría ayudar a los entrenadores de baloncesto a asegurar la optimización de las tareas de entrenamiento de sobrecarga, como podrían ser las de principio de microciclo, y mejorar las estrategias de sobrecompensación en las sesiones del final del microciclo y más cercanas a la competición.

8. APLICACIONES PRÁCTICAS

8.1. Estudio 1

- Tareas específicas de entrenamiento (e.g., juegos reducidos o 5 contra 5) deberían incluir una ratio de trabajo/descanso de entre 1:0,7 y 1:1,14, similar a lo encontrado en la competición oficial.
- Las múltiples diferencias entre posiciones de juego tendrían que ayudar a potenciar las metodologías de entrenamiento basadas en la individualización, especialmente en las áreas físicas y técnica en períodos fuera de temporada (e.g., *off-season* o *pre-season*) y después de haber acumulado poco tiempo de juego. A modo de ejemplo:
    - Pívots tendrían que estresar más las acciones de salto y contacto (e.g., empujes i tracciones) usando los juegos reducidos de 1 contra 1 y 2 contra 2 con objetivos de tiro, rebote o lucha aplicada.
    - Exteriores tendrían que focalizarse más en movimientos cortos e intermitentes de alta intensidad (e.g., desplazamientos defensivos y cambios de dirección).

8.2. Estudio 2

- Debido a que la metodología tradicional basada en valores promedios tiende a infravalorar las demandas físicas en jugadores de baloncesto, parece necesario complementar este enfoque con el análisis de EME.

- Los entrenadores de baloncesto tendrían que asegurarse que los jugadores reciben suficiente exposición en intensidades pico durante las tareas técnico-tácticas de sesiones de entrenamiento para optimizar la preparación para la competición.

8.3. Estudio 3

- El análisis de las demandas físicas de los jugadores de baloncesto mediante valores promedios infravalora los EME de 1 min. Los entrenadores de baloncesto deberían añadir el uso de los EME para la optimización del proceso de entrenamiento.
- Las demandas físicas mostraron mucha variabilidad entre las cinco categorías por edad analizadas, especialmente en distancia total y distancia recorrida a alta intensidad (>18 $km \cdot h^{-1}$). En consecuencia, los entrenadores de baloncesto deberían individualizar la exigencia física demandada a los jugadores durante entrenamientos mediante tareas con mayor volumen (promedio de distancia total) en categorías inferiores y mayor intensidad (EME de distancia total y distancia recorrida a alta intensidad) en categorías superiores.

8.4. Estudio 4

- Debido al análisis de los EME durante competición y su relación las diferentes sesiones de entrenamiento en función de la cercanía del partido, los entrenadores de baloncesto pueden asegurar la optimización en las sesiones de sobrecarga, como pueden ser la MD-4 y MD-3, así como mejorar las estrategias de sobrecompensación a corto plazo en las sesiones MD-2 y MD-1.

- Las múltiples diferencias entre posiciones de juego tendrían que ayudar a potenciar las metodologías de entrenamiento basadas en la individualización, especialmente en las áreas físicas y técnica en períodos fuera de temporada (e.g., *off-season* o *pre-season*) y después de haber acumulado poco tiempo de juego. A modo de ejemplo:
    - Aleros y ala-pívots tendrían que estresar más la distancia de alta intensidad usando los juegos reducidos o el 5 contra 5 a campo abierto.
    - Exteriores tendrían que focalizarse más en movimientos cortos e intermitentes de alta intensidad para potenciar tanto el número como la distancia en aceleraciones y desaceleraciones de alta intensidad.
- Los entrenadores podrían proponer partidos de entrenamiento de 5 contra 5 con el reglamento FIBA modificado (e.g., evitar tiros libres después de falta o poner el balón en juego rápido) para reducir interrupciones y promover una mayor sobrecarga y estimular los EME.

9. LIMITACIONES

Se han agrupado en seis las limitaciones acumuladas en los cuatro trabajos que configuran esta tesis doctoral:

1. A nivel profesional, solo tres equipos masculinos compitiendo en tres categorías diferentes (Euroliga y Liga Endesa o 1ª división española, temporada 2019/2020; Liga LEB Oro o 2ª división española, temporada 2018/2019; y Liga LEB Plata o 3ª división española, temporada 2019/2020) fueron monitorizados durante liga regular. En consecuencia, los resultados obtenidos no se pueden extrapolar a baloncesto femenino ni a otras categorías de baloncesto formativo o amateur, así como a otros tipos de calendario competitivo (*e.g., play-off*).
2. Cuando las posiciones de juego se utilizaron como variable independiente, se clasificó el total de jugadores en exteriores o *guards*, aleros y ala-pívots o *forwards*, y pívots o *centers*. Debido al reducido número de *forwards* y *centers* por equipo, las conclusiones pueden haber sido muy influenciadas por el estilo específico de juego de los jugadores categorizados en cada posición.
3. Todos los equipos analizados pertenecieron al mismo club y entrenaron y compitieron bajo el mismo modelo de juego. Este hecho no hace posible extrapolar los resultados de la presente tesis a otros equipos de clubes con otros contextos competitivos.
4. La presente tesis ha utilizado el uso exclusivo de valores promedios y EME de 1 minuto para el análisis de las demandas

físicas en baloncesto durante competición. Mientras que la utilización de los valores promedios podría menospreciar los EME, el uso exclusivo de la ventana temporal de 1 min podría no representar escenarios más prolongados durante competición.

5. En las tres investigaciones que han incorporado EME, su análisis siempre ha sido realizado desde una perspectiva cuantitativa. De este modo, las demandas pico en las variables seleccionadas (e.g., distancia total, distancia a alta velocidad o aceleraciones y desaceleraciones de alta intensidad) han sido utilizadas para comparar posiciones de juego, categorías de competición o sesiones de entrenamiento y partido sin tener en cuenta el contexto donde se producían (e.g., situaciones de ataque o defensa, con marcador a favor o en contra, posición clasificatoria propia y del rival, etc.).
6. Debido a que jugadores Sub-18 de alto nivel han demostrado alcanzar valores máximos de aceleración y desaceleración de 3,6 $m \cdot s^{-2}$ durante la competición, la utilización del umbral de 2 $m \cdot s^{-2}$ (55,5% del valor máximo posible) podría resultar insuficiente para la categorización de estas variables como alta intensidad. Además, el uso de umbrales absolutos para determinar la distancia a alta velocidad (>18 $km \cdot h^{-1}$) y las aceleraciones y desaceleraciones de alta intensidad (>2 $m \cdot s^{-2}$) pueden no permitir una directa comparación entre jugadores con diferente edad madurativa y capacidad condicional.

10. LÍNEAS FUTURAS DE INVESTIGACIÓN

A partir de las conclusiones de los estudios así como de las limitaciones previamente descritas se detallan a continuación las futuras líneas de investigación que podrían abordarse en próximos proyectos:

1. Análisis de las demandas físicas de jugadores y jugadoras de baloncesto durante competición en distintas categorías de baloncesto sénior, amateur y profesional, así como a otros tipos de calendario competitivo, como torneo con congestión de partidos.
2. Siguiendo la recomendación de Russell et al. (2020), simplificar el modelo más utilizado de tres posiciones de juego (*guards, forwards* y *centers*) por la categorización en dos posiciones de juego más generales: jugadores exteriores (bases, escoltas y aleros), o *backcourt/perimeter players*, y jugadores interiores (ala-pívots y pívots), o *frontcourt/inside players*.
3. Análisis de las demandas físicas de baloncesto en equipos que compitan en diferentes categorías de formación con distintos clubes y bajo modelos de juego diferentes, como por ejemplo estilos de juego más lentos que incorporen mayor número de ataques estáticos, o estilos de juego más directos donde se pretenda conseguir una finalización lo antes posible.
4. Si bien la utilización de EME de 1 minuto ya es un avance en la descripción de las demandas físicas mediante el método tradicional de promedios, la ventana temporal de 1 minuto de los escenarios pico debería complementarse con el análisis de ventanas menores (e.g., 15, 30, 45-s) y mayores (90-s, 1, 2, 3,

4, 5 min) en función de los objetivos y necesidades. Además del análisis de los EME de forma independiente, también sería interesante estudiar la repetibilidad de los escenarios de máxima y muy alta exigencia para averiguar si se producen como acciones aisladas o si, de lo contrario, tienden a repetirse durante la competición.

5. Análisis cualitativo de los EME añadiendo el contexto los que se producen. A modo de ejemplo, sería interesante analizar el efecto de la posesión de balón (situaciones de ataque y defensa) en las demandas físicas, así como las diferentes acciones técnico-tácticas ofensivas y defensivas. El nivel del rival y la fluctuación del marcador durante el partido y su influencia en los EME también podrían ser factores interesantes para investigar.
6. Análisis del perfil de aceleración y desaceleración en baloncesto durante competición para establecer el umbral de valor absoluto de alta intensidad. A modo descriptivo, si los valores máximos de aceleración se localizan entre 3,5 y 4 $m \cdot s^{-2}$, sería conveniente aumentar el umbral absoluto de >2 $m \cdot s^{-2}$ a >3 $m \cdot s^{-2}$ para asegurar que solo se analizan las aceleraciones de >80% del valor máximo.
7. Para individualizar los resultados de demandas físicas de alta intensidad entre diferentes jugadores, se propone utilizar umbrales relativos al valor máximo posible de cada jugador. A modo de ejemplo, se propone utilizar entre el 85 y el 90% de la velocidad máxima alcanzada para definir el umbral de distancia a alta intensidad, así como entre el 85 y el 90% de la aceleración máxima para definir el umbral de aceleración de alta intensidad. La definición de los valores máximos por

jugador bien podría establecerse en un test analítico previo a la competición, o bien aprovechar el valor máximo que cada jugador haya alcanzado durante tareas específicas de baloncesto durante entrenamiento o partido.

III. ANEXOS

TRABAJOS PUBLICADOS O ACEPTADOS PARA LA TESIS

ESTUDIO 1

DIFFERENCES IN PHSYICAL DEMANDS BETWEEN GAME QUARTERS AND PLAYING POSITIONS ON PROFESSIONAL BASKETBALL PLAYERS DURING OFFICIAL COMPETITION

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Research article

Differences in Physical Demands between Game Quarters and Playing Positions on Professional Basketball Players during Official Competition

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Abstract

The purpose of this study was to compare physical demands between game quarters and specific playing positions during official basketball competition. Thirteen professional male basketball players from the Spanish 2nd Division were monitored across all 17 regular-season home games. Physical demands were analyzed using a local positioning system (WIMU PRO™, Realtrack Systems S.L., Almería, Spain) and included peak velocity, total distance covered, high-speed running (>18 $km \cdot h^{-1}$), player load, jumps (>3G), impacts (>8G) and high-intensity accelerations (≥2 $m \cdot s^{-2}$) and decelerations (≤-2 $m \cdot s^{-2}$). A linear mixed model was used to test statistical significance ($p < 0.05$) between independent variables. Furthermore, standardized Cohen's effect size (ES) and respective 90% confidence intervals were also calculated. There was an overall decrease in all variables between the first and fourth quarter during competition. Specifically, total distance covered ($p < 0.001$; ES = -1.31) and player load ($p < 0.001$; ES = -1.27) showed large effects between the first and last period. Regarding differences between positions, guards presented significant increased values compared to centers ($p = 0.04$; ES = 0.51), whereas centers achieved significant larger results and moderate effects in comparison to guards in peak velocity ($p = 0.01$; ES = 0.88) and jumps ($p = 0.04$; ES = 0.86). In conclusion, physical demands vary between game quarters and playing positions during official competition and these differences should be considered when designing training drills to optimize game performance.

Key words: Acceleration, Game Analysis, Team Sport, Performance.

Introduction

Basketball is a stochastic physically demanding team sport in which both the aerobic and anaerobic energy systems are stressed during games (Stojanović et al., 2018). In addition to cognitive requirements, jumps, sprints, accelerations, decelerations and change of directions are crucial to perform specific movements in basketball (Taylor et al., 2017). For instance, rebounding, blocking, shooting, finishing, dribbling or defending in multiple directions are teams' means to achieve their ultimate goal, namely to score and not to concede points (Ben Abdelkrim et al., 2007; 2010a; McInnes et al., 1995). Thus, knowing physical demands during basketball competition could help coaches, athletic performance staff and medical staff to optimize training and game performance.

Previous investigations (McInnes et al., 1995; Oba and Okuda, 2011; Scanlan et al., 2012; 2015) have examined the physical demands of basketball through the use of video-based movement analysis methodologies based on a subjective visual prediction of sport-specific movement intensity. However, their validity and reliability were shown to be limited and they are also a time-consuming strategy (Barris and Button, 2008). Recently, advances in technology have allowed the use of inertial micro-sensors (Montgomery et al., 2010; Reina et al., 2019; Vázquez-Guerrero et al., 2018a) to quantify variables such as high-intensity accelerations, decelerations, jumps and impacts on semiprofessionals (Fox et al., 2018; Scanlan et al., 2019) and professional male basketball players (Svilar et al., 2018a; Vázquez-Guerrero et al., 2018a). Due to the fact that global positioning systems (GPS) only work outdoors (Puente et al., 2017), local positioning systems (LPS) also allow basketball practitioners to complement information from inertial devices with positioning-derived variables such as player speed and total distance covered in different speed zones. Furthermore, it is important to highlight that LPS has been shown to be valid and reliable (Bastida-Castillo et al., 2018) in monitoring players' physical requirements (Gómez-Carmonaet al., 2019; Vázquez-Guerrero et al., 2018b).

It is still controversial whether physical demands tend to diminish at the end of basketball games. While some studies (Scanlan et al., 2012; 2015) have not been able to report significant differences after the analysis of distance and speed parameters, other investigations have found a significant decrease between the first and last quarters in high-intensity actions (Ben Abdelkrim et al., 2007; 2010a; Delextrat et al., 2017; Reina et al., 2019; Vázquez-Guerrero et al., 2019b) and player load (Scanlan et al., 2019; Vázquez-Guerrero et al., 2019b), which presents a valid and reliable estimation of whole-body load provided by inertial micro-sensors (Nicolella et al., 2013). Nevertheless, to date no study has investigated the differences in physical exertion between quarters of official games among professional basketball players using LPS.

Besides being useful in studying possible changes between quarters, microtechnology has also been used to determine the differences in physical demands between specific playing positions. For instance, the exclusive use of inertial microsensors has been applied to report differences in activity demands on professional players across positional roles during training (Svilar et al., 2018b; Vázquez-Guerrero et al., 2018b) and competition (Reina et

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al., 2019; Vázquez-Guerrero et al., 2018a). Although the authors of this research have no knowledge of any study that have combined inertial devices with LPS to examine game demands on professional players, this methodology have already been used to detect differences in under-18 (U18) elite basketball players (Vázquez-Guerrero et al., 2019a; 2019b; 2019c). Therefore, the aim of this study was to describe and compare physical demands between quarters and specific playing positions among male professional basketball players using inertial devices and LPS during official competition.

Methods

Participants

The subjects in this research were professional male basketball players (mean ± SD, age: 19.8 ± 1.7 years; height: 2.00 ± 0.08 m; and body mass: 91.8 ± 15.9 kg), who competed with the same team in three different playing positions: guards (n = 7), forwards (n = 3) and centers (n = 3). All players belonged to a reserve squad of a Euroleague team and participated in the Spanish second division, namely LEB Oro, during the 2018/2019 season and finished in 17th position in the league after winning nine out of the regular season's thirty-four matches. All players and coaches agreed to participate by giving their written consent after being informed about the purpose of the investigation, the research protocol and requirements, as well as the benefits and risks associated with the study. Furthermore, no ethics committee approval was needed because the data were obtained after the players were routinely monitored during training and matches in the course of the competitive season (Winter and Maughan, 2009). Nevertheless, the study fulfilled the provisions of the Declaration of Helsinki (Harriss and Atkinson, 2015).

Design

This observational study was conducted to compare physical demands during official basketball competition. Thirteen elite basketball players were monitored during all 17 official home games in the 2018/2019 season (September-May). Players who suffered injury or played less than 10 minutes in a match were excluded, resulting in a total of 708 single records.

Methodology

All games were completed on the same court in similar environmental conditions. The team played one game a week, usually between Friday and Sunday, after a standard 45-minute warm-up consisting of individual skills such as dribbling, shooting and passing. Players were allowed to drink water ad libitum during recovery periods. Furthermore, the team followed the Futbol Club Barcelona`s "structured training" methodology, which has been specially designed to optimize team-sports performance and is based on coadjuvant and optimizer training. While the former training type aims to allow players to train and maximize their conditional capabilities, the latter focuses on allowing basketball players to compete and perform at their highest potential in competition (Gómez et al., 2019; Martín-García et al., 2018; Tarragó et al., 2019)

Physical demands

Player movements were recorded using WIMU PRO™ (Realtrack Systems S.L., Almería, Spain), which includes four 3D accelerometers (full-scale output ranges are ±16 g, ±16 g, ±32 g, ±400 g. 100 Hz sample frequency), a gyroscope (8000º/s full-scale output range. 100 Hz sample frequency), a 3D magnetometer (100 Hz sample frequency), a GPS (10 Hz sample frequency) and an ultra-wide band positioning system (18 Hz sample frequency). Each inertial device (81x45x16 mm, 70 g) has a gigahertz microprocessor, 8GB flash memory and a high-speed USB interface to record, store and upload data. The units were placed in a custom-made vest located in the center area of the upper back using an adjustable harness, as recommended by the manufacturer (IMAX, Lleida, Spain).

As in previous studies (Puente et al., 2017; Stojanović et al., 2018; Vázquez-Guerrero et al., 2018a), the following variables were used to monitor physical demands, including: A) peak velocity (PV) in $km \cdot h^{-1}$, as the highest value obtained during each game; B) total distance covered (TDC) in meters; C) distance covered >18 $km \cdot h^{-1}$ (D18) in meters; D) player load (PL), expressed in arbitrary units and calculated as the sum of the squared rates of change in acceleration (also known as jerk) in each of the three vectors divided by 100 (Fox et al., 2018; Nicolella et al., 2013; Vázquez-Guerrero et al., 2019c) and E) the number of impacts that surpassed 8 g-forces (IMP), jumps above 3 g-forces (JUM) and high-intensity accelerations (≥2 $m \cdot s^{-2}$) (ACC) and decelerations (≤-2 $m \cdot s^{-2}$) (DEC) (Vázquez-Guerrero et al., 2019b; 2019c). In order to compare the activity of players with different playing times, all the variables were normalized by the total time spent on court, defined as the sum of all time that players were on court, excluding only breaks between periods but including all stoppages (Scanlan et al., 2015).

WIMU PRO™ has been shown to have good/acceptable accuracy and inter- and intra-unit reliability for ultra-wide band positioning (Bastida-Castillo et al., 2019; Bastida-Castillo et al., 2019; Bastida Castillo et al., 2018; Gómez-Carmona et al., 2019). This system includes six antennas with ultra-wide band technology positioned 12 meters away from the sidelines of the basketball court. A total of three antennas are placed in each baseline, 17 meters apart, forming a rectangle for better signal emission and reception. All of them were located at a height of seven and half meters from the wooden floor and were connected and calibrated following the manufacturer's instructions. Data were downloaded and analyzed using the manufacturer's specific software (SPRO™, version 950, RealTrack Systems, Almería, Spain).

Statistical analyses

Descriptive data from official competition were reported as mean ± standard deviation (SD). The Pearson correlation matrix with eight performance variables was analyzed to perform a visual inspection of data factorability. Differences in physical demands outcomes 1) between game quarters, and 2) between playing positions, respectively, were assessed fitting linear mixed models. This allowed the authors to model the dependence structure among dependent variables for longitudinal or repeated measures data. The physical demands variables were set as the dependent variable; game quarters (first, second, third and fourth quarter) and playing positions (guard, forward and center) were included as fixed effects; and players were considered as random effects. The significance of the fixed effects associated with the covariate included in the model was assessed using the Wald test. The statistical significance was set at $p < .05$. After the models were validated, the residuals of the final models were explored for normality, homogeneity and independence assumptions. Normality assumption of the residuals was checked by means of a normal q-q plot of residuals. All data analyses were performed using the Statistical Package for Social Sciences (version 25 for Windows; SPSS, Chicago, IL, USA) and R (The R Foundation for Statistical Computing, Vienna, Austria), R version 3.3.2 (R Core Team, 2016), with the package nlme and lmerTest.

Cohen's effect size (ES) and respective 90% confidence intervals were also calculated. Thresholds for effect size statistics were <0.20, trivial; 0.20-0.59, small; 0.60-1.19, moderate; 1.20-1.99, large; and >2.0, very large (Hopkins et al., 2009). The effect size analyses' calculations were performed with a customized Excel spreadsheet (downloaded and adapted from www.cem.org/effect-size-calculator).

Results

Physical demands for all players between quarters and specific position are shown in Table 1 (means, SD and significant difference), whereas Cohen's d effect size analysis is shown in Figures 1 and 2. Additionally, results from linear mixed models are shown in detail in Table 2 (supplemental material). Total duration for each quarter was as follows: 17.5 ± 1.4 min in the first quarter; 22.9 ± 2.3 min in the second quarter; 20.1 ± 2.1 min in the third quarter; and 23.9 ± 3.3 min in the fourth quarter. This means that the so-called work-to-rest ratio, i.e. the relationship between effective playing and rest time, would be 1:0.7 in the first quarter, 1:1.3 in the second quarter, 1:1 in the third quarter and 1:1.4 in the fourth quarter. Thus, 2Q and 4Q presented the lowest work-to-rest ratios due to a higher number of game interruptions.

The first quarter presented significant differences and small to large effects with the other three quarters in almost all game variables. For instance, the largest differences between the first and fourth quarter were found in TDC ($p < 0.001$; ES = -1.31) and PL ($p < 0.001$; ES = -1.27). Moreover, these two variables also presented significant differences and moderate effects between the third and fourth quarter (TDC $p < 0.001$ and ES = -0.75; PL $p < 0.001$ and ES = -0.72) and between the first and second quarter ($p < 0.001$ and TDC ES = -1.14; PL $p < 0.001$ and ES = -1.08). Additionally, ACC ($p < 0.001$; ES = -0.78) and DEC ($p < 0.001$; ES = -0.67) showed moderate decreases in the fourth quarter compared to the first quarter.

In addition to differences between game quarters, TDC, PV and JUM also showed significant differences between guards and centers. More specifically, centers achieved the lowest values in TDC compared to guards ($p = 0.04$; ES = 0.51) and forwards ($p < 0.05$; ES = 0.47). On the contrary, centers presented the highest values in PV and JUM compared to guards (PV $p = 0.01$ and ES = 0.88; JUM $p = 0.04$ and ES = 0.86) and forwards (PV $p < 0.05$ and ES = 0.57; JUM $p < 0.05$ and ES = 1.07). Furthermore, game variables such as D18, PL, ACC, DEC and IMP did not present significant differences.

Table 1. **Means (±SD) in selected physical demands for quarters and playing positions.**

		Peak Velocity (km·h^{-1})	Total distance covered (m)	Distance > 18 Km·h^{-1} (m)	Player load (a.u.)	Accelerations > 2 m·s^{-2} (counts)	Decelerations < 2 m·s^{-2} (counts)	Jumps > 3 G (counts)	Impacts > 8 G (counts)
PLAYERS (n = 13)	1Q	20.2 ± 1.6†	83.1 ± 9.8†‡§	3.9 ± 2.5†§	1.5 ± 0.2†‡§	4.1 ± 1.2†‡§	3.7 ± 1.2†‡§	0.3 ± 0.2†§	1.4 ± 1.1†§
	2Q	20.1 ± 1.5*	71.6 ± 9.3*‡	3.0 ± 2.0*‡	1.3 ± 0.2*‡§	3.4 ± 1.1*‡	3.1 ± 1.1*‡	0.2 ± 0.2*	1.3 ± 1.0*
	3Q	20.2 ± 1.6	77.1 ± 9.1*†§	3.5 ± 1.8†§	1.4 ± 0.2*†§	3.7 ± 1.1*†§	3.3 ± 1.1*†§	0.3 ± 0.2§	1.4 ± 1.0§
	4Q	20.2 ± 1.5	69.8 ± 9.5*‡	2.9 ± 1.9*‡	1.2 ± 0.2*†‡	3.2 ± 1.1*‡	2.9 ± 1.2*‡	0.2 ± 0.2*‡	1.1 ± 0.9*‡
	TOTAL	20.7 ± 1.5	72.4 ± 8.1	3.2 ± 1.2	1.3 ± 0.2	3.5 ± 1.0	3.1 ± 1.0	0.2 ± 0.1	1.3 ± 0.9
GUARD (n = 7)	1Q	19.8 ± 1.3	84.2 ± 9.3	3.5 ± 1.9	1.5 ± 0.2	4.5 ± 1.0	3.8 ± 1.0	0.2 ± 0.2	1.3 ± 0.8
	2Q	19.7 ± 1.1	73.0 ± 10.1	2.7 ± 1.7	1.3 ± 0.2	3.6 ± 1.0	3.2 ± 0.9	0.2 ± 0.2	1.1 ± 0.7
	3Q	19.9 ± 1.2	78.3 ± 7.9	3.2 ± 1.5	1.4 ± 0.2	3.8 ± 0.7	3.4 ± 0.8	0.2 ± 0.2	1.3 ± 0.9
	4Q	19.8 ± 1.3	72.1 ± 10.5	2.7 ± 1.6	1.2 ± 0.2	3.4 ± 1.0	3.1 ± 1.0	0.1 ± 0.2	1.0 ± 0.6
	TOTAL	20.2 ± 1.2¶	73.6 ± 8.6¶	2.9 ± 1.1	1.3 ± 0.1	3.7 ± 0.9	3.3 ± 0.9	0.2 ± 0.1¶	1.1 ± 0.6
FORWARD (n = 3)	1Q	20.1 ± 1.6	84.6 ± 10.2	4.1 ± 3.0	1.4 ± 0.2	3.9 ± 1.2	3.4 ± 1.2	0.2 ± 0.1	1.1 ± 0.9
	2Q	20.3 ± 1.5	72.6 ± 9.3	3.4 ± 2.3	1.2 ± 0.2	3.2 ± 1.0	2.9 ± 1.1	0.2 ± 0.1	1.0 ± 0.8
	3Q	20.1 ± 1.4	78.2 ± 8.2	3.9 ± 2.2	1.3 ± 0.2	3.5 ± 1.1	3.0 ± 1.1	0.2 ± 0.2	1.0 ± 0.7
	4Q	20.3 ± 1.5	68.4 ± 8.9	2.9 ± 1.9	1.1 ± 0.2	2.9 ± 1.0	2.5 ± 1.1	0.2 ± 0.1	0.8 ± 0.7
	TOTAL	20.6 ± 1.3	73.5 ± 7.5	3.3 ± 1.3	1.2 ± 0.1	3.2 ± 0.9	2.8 ± 0.9	0.2 ± 0.1	0.9 ± 0.6
CENTER (n = 3)	1Q	21.3 ± 1.8	78.6 ± 9.3	4.6 ± 2.8	1.6 ± 0.3	4.2 ± 1.6	3.8 ± 1.4	0.5 ± 0.3	2.3 ± 1.4
	2Q	20.5 ± 1.9	66.7 ± 11.3	3.2 ± 2.0	1.3 ± 0.3	3.4 ± 1.3	3.1 ± 1.4	0.3 ± 0.2	2.1 ± 1.5
	3Q	21.2 ± 2.1	73.0 ± 11.5	3.6 ± 1.8	1.4 ± 0.3	4.0 ± 1.5	3.5 ± 1.5	0.4 ± 0.3	2.1 ± 1.1
	4Q	21.2 ± 1.2	66.4 ± 11.7	3.3 ± 2.2	1.3 ± 0.3	3.3 ± 1.4	3.0 ± 1.5	0.4 ± 0.2	2.1 ± 1.2
	TOTAL	21.8 ± 1.7‖	68.2 ± 6.7‖	3.5 ± 1.3	1.3 ± 0.2	3.6 ± 1.3	3.3 ± 1.3	0.4 ± 0.2‖	2.2 ± 1.2

1Q is first quarter, 2Q is second quarter, 3Q is third quarter and 4Q is fourth quarter. Significant differences (SD) are shown as follows: * = SD with 1Q; † = SD with 2Q; ‡ = SD with 3Q; § = SD with 4Q; || = SD with guard; ** = SD with forward; ¶ = SD with center.

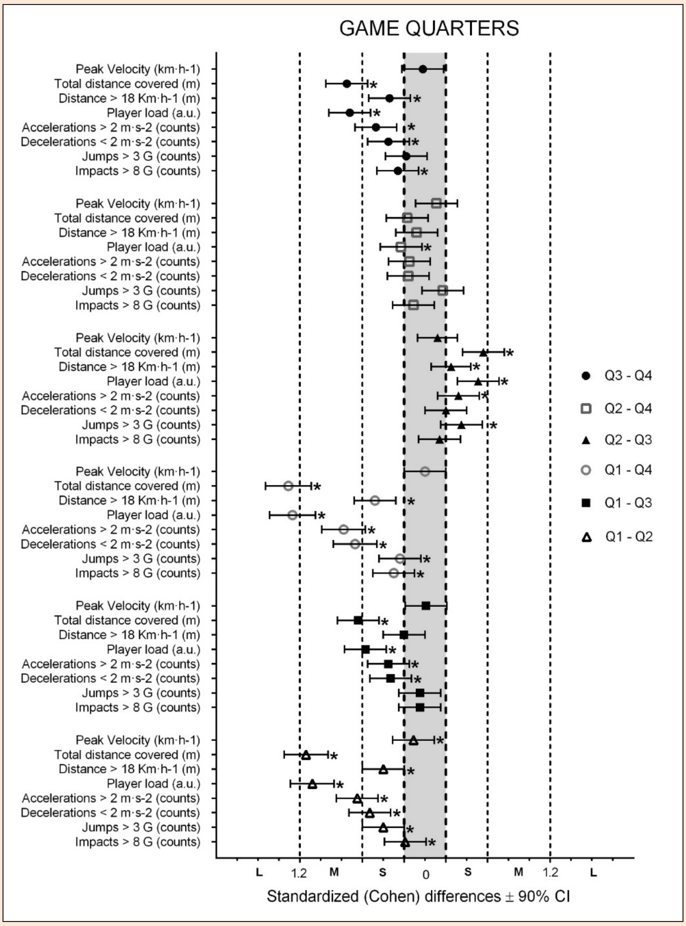

Figure 1. Standardized differences (Cohen's d) and the 90% CI between game quarters for the eight load variables selected. Significant difference is reported with * at the right end of the 90% CI bar. 1Q = first quarter; 2Q = second quarter; 3Q = third quarter; 4Q = fourth quarter; L = Large effect; M = Moderate effect; S = Small effect.

Discussion

The aim of this investigation was to compare professional basketball players' physical demands between quarters and playing positions during official competition. There were several novel findings that can help to achieve a better understanding of athletic performance in games, such as a significant decrease in TDC, PL, D18, ACC, DEC and JUM in the fourth quarter and the significant differences discovered in PV, TDC and JUM between guards and centers. These changes may partly be explained by the specific score, the team's playing model, the player's individual physical exertion and the inherent demands of the specific playing position (Ben Abdelkrim et al., 2007; Scanlan et al., 2015).

Similar to previous research that used total time to normalize absolute values of physical exertion in U18 (Vázquez-Guerrero et al., 2019b) and U19 basketball players (Ben Abdelkrim et al., 2007; 2010b), this investigation also found a significant decrease in the fourth quarter compared to the first quarter in game variables such as TDC, D18, PL, ACC and DEC. However, it still remains controversial whether there is such a variation in physical demands among game quarters after some studies failed to present similar conclusions using live time (Oba and Okuda, 2011; Scanlan et al., 2015). Thus, the use of total time instead of live time (Scanlan et al., 2012) is crucial to understanding these results, since the current research did find significant reductions in the majority of variables studied when period total time was greater. Additionally, it

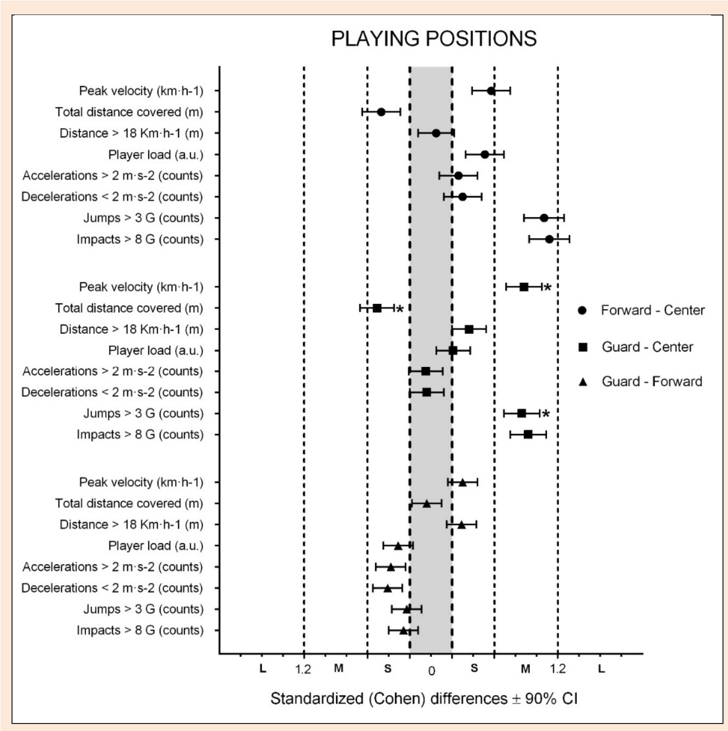

Figure 2. Standardized differences (Cohen's d) and the 90% CI between playing positions for the eight load variables selected. L = Large effect; M = Moderate effect; S = Small effect. Significant difference is reported with * at the right end of the CI bar.

should be mentioned that similar conclusions have been drawn in football, where physical demands do not seem to decrease significantly during matches when live time, or the so-called "effective playing time", is analyzed instead of total time (Castellano et al., 2011; Linke et al., 2018). In addition to this methodological difference, it must also be noted that game pace could diminish in the fourth quarter due to a possible team strategy, with fewer transitions and fewer players involved in each offensive possession. Therefore, caution should be exercised when concluding that the appearance of fatigue might be the cause of a reduction in performance load variables at the end of basketball games (Ben Abdelkrim et al., 2010a).

Although differences between game quarters in all game variables have been found, this research only detected significant differences in TDC, PV and JUM between guards and centers. For instance, TDC was found to be significantly lower in centers compared to guards in this investigation. Available research (Vázquez-Guerrero et al., 2019c) reported similar results (TDC centers = 68.2 m·min^{-1}; TDC forwards = 72.6 m·min^{-1}; TDC guards = 74.4 m·min^{-1}) in U18 elite basketball players. These findings could be explained by the fact that centers tend to remain in more static positions near the three-second zone during set pieces for tactical reasons. As well as TDC, previous studies (Puente et al., 2017; Vázquez-Guerrero et al., 2019c) also reported that centers obtained the lowest values in PV and D18. Conversely, this investigation found that centers achieved the highest PV (21.8 km·h^{-1}) and completed the largest number of meters above 18 km·h^{-1} (3.5 m·min^{-1}) compared to guards (PV = 20.2 km·h^{-1}; D18 = 2.9 m·min^{-1}) and forwards (PV = 20.6 km·h^{-1}; D18 = 3.3 m·min^{-1}). One possible explanation for centers achieving significantly higher maximal speeds and completing more high-speed running distance could be that they usually cover more meters in offensive and defensive transitions from basket to basket and therefore have more time to achieve higher velocities. In addition to TDC and PV, data from inertial micro-sensors also showed differences between positions. In line with previous research (Ben Abdelkrim et al., 2007), the number of jumps averaged by centers (n = 49) tended to be significantly higher than all playing positions (n = 41), possibly due to their shot-blocking and rebounding role. Besides the effort to jump, centers also presented more moderate increased values in IMP than guards and forwards, which can complement the information presented above to describe the specific physical demands of the center position.

Despite the fact that the available research presented inconsistent results when PL among playing positions during competition was compared (Vázquez-Guerrero et al., 2018a; Vázquez-Guerrero et al., 2019c), this research

Table 2. **Linear mixed models with selected physical demands parameters as dependent variable.**

	PV					TDC					D18					PL				
Variables	**ES**	**SE**	**95% CI**	**t**	**p**	**ES**	**SE**	**95% CI**	**t**	**p**	**ES**	**SE**	**95% CI**	**t**	**p**	**ES**	**SE**	**95% CI**	**t**	**p**
Intercept	19.66	0.27	19.12-20.19	72.18	<0.01	71.62	1.62	68.46-74.77	44.61	<0.01	2.44	0.35	1.76-3.13	6.98	<0.01	1.23	0.05	1.14-1.33	25.62	<0.01
Center	1.53	0.45	0.52-2.54	3.38	<0.01	-6.11	2.58	-11.87-(-0.36)	-2.37	0.04	0.87	0.57	-0.40-2.13	1.53	0.16	0.04	0.08	-0.15-0.22	0.47	0.65
Forward	0.55	0.44	-0.44-1.53	1.24	0.24	-1.32	2.49	-6.88-4.24	-0.53	0.61	0.64	0.55	-0.58-1.87	1.16	0.27	-0.09	0.08	-0.27-0.10	-1.06	0.32
1Q	-0.03	0.17	-0.36-0.29	-0.19	0.85	13.61	1.13	11.39-15.84	12.02	<0.01	1.06	0.24	0.59-1.53	4.46	<0.01	0.28	0.02	0.24-0.33	11.92	<0.01
2Q	-0.15	0.16	-0.47-0.17	-0.92	0.36	1.82	1.11	-0.37-4.01	1.63	0.10	0.17	0.23	-0.29-0.63	0.74	0.46	0.05	0.02	0.01-0.10	2.29	0.02
3Q	0.01	0.16	-0.32-0.33	0.04	0.97	7.51	1.11	5.32-9.71	6.72	<0.01	0.63	0.23	0.17-1.09	2.71	<0.01	0.16	0.02	0.11-0.21	6.80	<0.01
σ_u			0.60					3.31					0.74					0.11		
σ_ϵ			1.36					9.25					1.94					0.19		

	ACC					DEC					JUM					IMP				
Variables	**ES**	**SE**	**95% CI**	**t**	**p**	**ES**	**SE**	**95% CI**	**t**	**p**	**ES**	**SE**	**95% CI**	**t**	**p**	**ES**	**SE**	**95% CI**	**t**	**p**
Intercept	3.40	0.20	3.01-3.80	17.04	<0.01	3.04	0.20	2.66-3.42	15.58	<0.01	0.17	0.04	0.10-0.25	4.61	<0.01	1.16	0.33	0.52-1.81	3.54	<0.01
Center	0.11	0.33	-0.62-0.85	0.35	0.74	0.12	0.32	-0.59-0.83	0.39	0.71	0.15	0.06	0.1-0.30	2.39	0.04	0.93	0.59	-0.38-2.25	1.58	0.14
Forward	-0.44	0.32	-1.15-0.27	-1.37	0.20	-0.44	0.31	-1.13-0.25	-1.42	0.19	-0.01	0.06	-0.15-0.13	-0.18	0.86	-0.35	0.59	1.66-0.96	-0.60	0.56
1Q	0.91	0.13	0.66-1.16	7.12	<0.01	0.78	0.13	0.52-1.03	5.99	<0.01	0.05	0.02	0.01-0.09	2.33	0.02	0.29	0.08	0.13-0.46	3.47	<0.01
2Q	0.15	0.13	-0.10-0.39	1.16	0.25	0.16	0.13	-0.09-0.41	1.27	0.21	-0.02	0.02	-0.06-0.01	-1.23	0.22	0.13	0.08	-0.03-0.29	1.55	0.12
3Q	0.48	0.13	0.24-0.73	3.84	<0.01	0.37	0.13	0.12-0.63	2.94	<0.01	0.04	0.02	-0.00-0.07	1.83	0.07	0.22	0.08	0.06-0.38	2.63	<0.01
σ_u			0.43					0.42					0.09					0.84		
σ_ϵ			1.03					1.04					0.16					0.68		

1Q is first quarter, 2Q is second quarter, 3Q is third quarter, σ_u is a standard deviation of player; σ_ϵ is a standard deviation of residual, ES is coefficient estimate, SE is Standard Error, 95% CI is 95% confidence intervals, t is t-value and p is p-value. We have used "guard" in the playing position variable and "fourth quarter" in the game quarter variable as reference categories for this model.

did not find significant differences between specific positions in this inertial-derived variable. In line with previous research using the same technology with U18 male (Vázquez-Guerrero et al., 2019c) and female players (Reina et al., 2019), this investigation showed that guards perform the highest amount of ACC and DEC, possibly due to a performance of a great number of high-intensity movements such as full-court defense, one-on-one attacks to beat the opponent or actions after different types of screens (Sampaio et al., 2006). Conversely, the present research showed that forwards presented the lowest values in PL, ACC and DEC. Furthermore, recent studies have also concluded that centers presented the lowest number of high-intensity ACC and DEC actions per minute (Reina et al., 2019; Vázquez-Guerrero et al., 2019c). The fact that centers and forwards presented these lower results during competition would be due to two logical principles: 1) big players are usually required to occupy smaller spaces around the basket for tactical reasons (Schelling and Torres, 2016); and 2) bigger players have to apply higher forces to accelerate due to their increased body mass (Ben Abdelkrim et al., 2007; Schelling and Torres, 2016). On the contrary, Svilar et al. (2018b) concluded that centers achieved the highest number of total and high-intensity accelerations and forwards managed to accomplished the highest number of total and high-intensity decelerations during 26 in-season training sessions in professional male basketball players. Therefore, positional role requirements could reflect the specificity of basketball playing positions across training and competition modes.

There are some limitations of this study that should be considered. Firstly, the authors acknowledge that monitoring one team formed with 13 under-20 young basketball players represents a small exclusive sample size. However, this professional team competed in the Spanish 2nd Division (LEB Oro), which constitutes a small exclusive convenience sample. Secondly, the fact that it was only possible to categorize three players as forwards and three different players as centers means that conclusions were reduced to their specific playing style. Finally, another potential limitation could be the use of game load averages to describe competition demands. Therefore, future research should analyze player's physical demands during the most demanding basketball scenarios, also referred to as "worst-case scenarios", to optimize game performance.

Conclusion

The findings from the current study indicate that the physical match demands are different between game quarters and playing positions in professional basketball. Although the players' fatigue could have a negative effect on some game load variables in the fourth quarter, tactical principles, including more stoppages and consequently a longer period duration, could better explain the game load output in the last quarter of the game. Furthermore, understanding the fact that players have different needs could help to bolster training methodologies based on individualization, especially in physical and technical areas.

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Key points

- The highest basketball-specific tasks should include an adequate work-to-rest ratio, namely playing small-sided games or 5 on 5 with a specific official competition density between 1:0.7 and 1:1.4.
- Players should work on their position-specific requirements, especially during off-season and after having accumulated little playing time during competition. For instance:
- Centers should stress more both jumping and contact actions (e.g. pushing and holding) using small-sided games such as 1 on 1 or 2 on 2 situations with the goal of shooting or rebounding.
- Guards should focus more on short and intermittent high-intensity movements, such as defensive shuffle and changes of directions.

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ESTUDIO 2

IS IT ENOUGH TO USE THE TRADITIONAL APPROACH BASED ON AVERAGE VALUES FOR BASKETBALL PHYSICAL PERFORMANCE ANALYSIS?

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Running title: The most demanding scenarios of basketball match-play

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ABSTRACT

Understanding the most demanding scenarios of basketball match-play can optimise training prescription. We established physical demand differences in total distance covered, distance covered at high-speed running, distance covered at high-intensity accelerations and decelerations, number of high-speed running actions and number of high-intensity accelerations comparing the traditional average method with the most demanding scenarios based on 1-minute rolling averages. Physical demand parameters were analysed from 21 elite basketball players according to playing position during a friendly game via local positioning system microtechnology. The results showed that players covered a total distance of 141.3 m·min^{-1} ($p < 0.001$; ES = 7.80) and 25.4 m·min^{-1} ($p < 0.001$; ES = 4.52) at high-speed running using rolling averages, compared to 66.3 m·min^{-1} and 3.2 m·min^{-1}, respectively, using the traditional average approach. These data represent a very large increase of 113.1% for total distance per minute and 686.4% for high-speed running distance per minute, 252% for the number of high-intensity accelerations and 290.5% for the number of high-intensity decelerations, respectively, demonstrating the relevance of this novel approach. In conclusion, this investigation indicated that the traditional average method underestimates peak physical demands over a 1-minute period during a basketball game. Thus, the average approach should be complemented by analysing the most demanding scenarios in order to have a better understanding of physical demands during basketball competition.

KEY WORDS: Worst-case scenario, movement demands, game analysis, inertial movement sensors, team sport

HIGHLIGHTS

- The traditional approach based on average values largely underestimates the most demanding 1-minute scenarios of basketball match-play.
- The prescription of training and return-to-play basketball-specific drills should be based on the most demanding scenarios to allow players to cope with peak physical requirements during competition.
- The most demanding scenarios of basketball match-play complement average values when designing effective individualised position-specific training interventions.

INTRODUCTION

Basketball is a complex and physically demanding court-based team sport that produces stress on both the anaerobic and aerobic systems during matches (Stojanović et al., 2018). The players perform substantive explosive accelerations, sprints, impacts and jumps based on specific movements, such as lay-ups, driving, closing out, jump shooting, fast breaks and high-speed shot blocking (Ostojic et al., 2006; Scanlan et al., 2011; Stojanović et al., 2018). Understanding the influence of physical demands during competitive matches and training sessions on injury prevention and sports performance should be considered as vital in sport medicine and for sport scientists and strength and conditioning coaches (Soligard et al., 2016).

It has been hypothesised that unsuitable workloads would lead to an increased incidence of injuries or reduced sport performance (Orchard, 2012). Consequently, the design, implementation, monitoring and management of training sessions that enable basketball players to deal with game play is a fundamental task for strength and conditioning professionals and coaches. Therefore, knowledge of players' physical demand averages based on movements such as the number of high-intensity accelerations, decelerations and distance covered at different speeds during basketball game play has been analysed previously (Fox et al., 2018; Klusemann et al., 2013; Pino-Ortega et al., 2019; Portes et al., 2020; Reina et al., 2019a; Svilar et al., 2018; Vázquez-Guerrero et al., 2019a; Vázquez-Guerrero et al., 2019b) games-based training (GBT. Additionally, available research has also shown significant differences in average game physical demands across playing positions in senior players using microtechnology (García et al., 2020; Reina et al., 2020).

Technological advances have rendered it possible to utilise ultra-wide band-based local positioning systems (LPS) to track players indoor (Serpiello et al., 2017), providing better levels of validity and reliability than standard GPS systems. The accuracy of LPS can be considered suitable for practical applications in sport analyses since position estimations are very precise and acceptable for tactical analyses. Furthermore, the error of the position estimations does not change significantly across different courses and the use of different devices does not significantly affect the measurement error (Bastida-Castillo et al., 2019). Research using LPS has analysed physical demands when rules of 5-on-5 scrimmage situations in elite basketball are modified during training sessions (Vázquez-Guerrero et al., 2018) and during official U-18 basketball games using the traditional approach based on average values (Vázquez-Guerrero et al., 2019c; Vázquez-Guerrero et al., 2019a; Vázquez-Guerrero et al., 2019b). Nevertheless, the benefits of these data as a point of departure for preparing team sport players is questionable because the phases in matches in which players present greater physical demands are underestimated (Delaney et al., 2015; Furlan et al., 2015; Varley et al., 2012). Furthermore, microtechnology promotes the application of a novel approach to analyse sports performance based on the identification of peak physical demands, also called most demanding scenarios or worst-case scenarios of match play, using rolling average techniques. This proposal yields novel and crucial information that may complement previous studies reporting traditional average physical demands of game play in basketball.

Previous research has analysed the most demanding physical demand scenarios during games in outdoor team sports such as soccer, Australian football, rugby and Gaelic football using different time average rolling epochs (Whitehead et al., 2018). Therefore, traditional average values must be complemented by the most demanding scenarios by means of the rolling average technique in order to prescribe adequate training drills that enable players to fulfil game requirements. However, no published studies have studied physical demands during basketball games using this novel approach.

Therefore, the main purpose of this study was to compare the traditional average method with the most demanding 1-minute scenarios of game play in basketball through a number of physical demand measures during a friendly elite basketball game. A secondary purpose was to identify whether there were differences in physical demands among playing positions. Information in this regard will be helpful to trainers and strength conditioning coaches to optimise players' specific performance during training and to improve the post-injury rehabilitation process.

METHODS

Participants

Twenty-one male elite basketball players (age: 27.9 ± 3.9 years; height: 200.1 ± 11.3 cm; body mass: 94.6 kg ± 11.8) who competed in two different elite teams (Euroleague and Spanish league) were monitored during a pre-season friendly match. In accordance with previous basketball research (Ibáñez et al., 2018; Sampaio & Calvo, 2008), players were divided into three playing positions: guards (n=11), forwards (n=5) and centres (n=5). Prior to participation, the experimental procedures and potential risks were fully explained to players and coaches verbally and in writing, and their written informed consent was obtained. The experimental procedures used in this study fulfilled the Declaration of Helsinki (Harriss & Atkinson, 2015) and no ethics committee approval was needed after the data were routinely obtained during the players' league games (Winter & Maughan, 2009).

Procedures

A descriptive study design was used to address the purposes of this research. Match-play was according to official FIBA rules. The match started with a 20-minute warm-up based on ball dribbling, shooting, specific mobility and dynamic stretching exercises. During match-play, all the players were continuously monitored, although physical demands were only quantified when players were actually on the court playing (i.e., time as substitutes or rest time between quarters was not included). The players were not required to observe any previous dietary recommendation or restriction but they were allowed to drink water ad libitum during the game recovery periods. The players' data were included for analysis provided that they were not injured during the match and that they played for at least 5 minutes (Vázquez-Guerrero et al., 2019a).

Based on recent recommendations regarding data collection quality (Rico-González et al., 2020), this current research observed certain considerations: 1) the technology used was ultra-wide band (UWB), which occupies a very large frequency band, at least 0.5 GHz; 2) for analysis purposes, the UWB system was calibrated and the WIMU PRO devices were synchronised to the UWB system 1 h before the start of the game through the antennas and the technology; 3) there was no metallic material in the vicinity of the antennas;

and 4) the system used time difference of arrival (TDOA), one of the most widely-used localization schemes that records the arrival time of the source signal. Player movements were measured using a portable LPS (WIMU PRO, Realtrack Systems S.L., Almería, Spain) during matches. The devices (81x45x15 mm, 70 g) were fitted to each player's upper back using an adjustable harness (Rasán, Valencia, Spain). The WIMU PRO units integrate different sensors recording at different sample frequencies. Sampling frequency for 3-axis accelerometer, gyroscope and magnetometer was 100 Hz, and 120 kPa for the barometer. For better signal emission and reception, the system has six ultra-wideband antennas placed in a hexagon: four of them placed six metres outside the court corners and two of them seven metres outside the half-way line. All antennas were positioned at a height of six meters and the sampling frequency for positioning data was 18 Hz. The system operates using triangulations between the antennas and the units, the six antennas send a signal to the units every 50 ms. The device then calculates the time required to receive the signal and derives the unit position (coordinates X and Y) using one of the antennas as a reference.

WIMU PRO software was used for the computation of rolling averages over each physical demand measure of interest using 60-s epoch, and the maximum value was recorded to compare with averages relative to the minute. For example, for a 60-s epoch length, the software identified the 1,080 consecutive data points (i.e., 18 samples for 60 s) in which the subject exhibited the greatest relative demand. In each epoch length, the peak values of the physical demands selected were recorded independently, hence it is very likely that they came from different data points. The traditional average method used the absolute value relative to the total time the player was competing on the court.

Maximum values using seven physical demand measures were therefore calculated for the rolling average technique and for traditional averages. More particularly, the following physical demand variables were measured and reported: a) relative distance ($m\cdot min^{-1}$); b) distance covered at high-speed running (>18 $km\cdot h^{-1}$); c) number of high-speed running actions (>18 $km\cdot h^{-1}$) d) distance covered in high-intensity accelerations (>2 $m\cdot s^{-2}$) and decelerations (<-2 $m\cdot s^{-2}$) and e) number of high-intensity accelerations (>2 $m\cdot s^{-2}$) and decelerations (<-2 $m\cdot s^{-2}$).

The LPS presented acceptable accuracy for measures of speed and mean acceleration and deceleration for intermittent activities (Stevens et al., 2014). The WIMU PRO has shown adequate reliability to measure team sport-specific movements, presenting a better accuracy (bias: 0.57–5.85%), test–retest reliability (%TEM: 1.19) and inter-unit reliability (bias: 0.18) in determining distance covered than GPS technology (bias: 0.69–6.05%; %TEM:1.47; bias: 0.25) overall (Bastida Castillo et al., 2018). More recently, the WIMU PRO system presented a mean absolute error of 5.2 ± 3.1 cm for the x position and 5.8 ± 2.3 cm for the y position. This represents percentage differences of 0.97 ± 1% for the x coordinate and 0.94 ± 1.14% for the y coordinate. The inter-unit reliability presented a large ICC for the x coordinate (0.65), a very large ICC for the y coordinate (0.88), and a good %TEM (2%) was reported for the error agreement between the two devices assessed. The accuracy of the UWB technology has also been tested indoors, showing high sensitivity to relative positioning on the court (Bastida-Castillo et al., 2019).

Statistical analysis

The data are presented as means ± standard deviations (SD). Following Shapiro-Wilk's test of normality and Levene's test of variance, physical demand parameters that followed a normal distribution were examined through the application of repeated measures ANOVA and Bonferroni post hoc test to detect differences between methods (average and 1-MDS) and playing positions (guards, forwards and centres). Dependent variables that did not present a normal distribution, such as the number of high-speed running actions (>18 km·h^{-1}) and the number of high-intensity accelerations (>2 m·s^{-2}) and decelerations (<-2 m·s^{-2}), were analysed using Friedman non-parametric ANOVA and Conover's post hoc test. All data analyses were performed using the JASP v0.9.2 software (University of Amsterdam, https://jasp-stats.org/) and the statistical significance was set at $p \leq 0.05$. Furthermore, Cohen's d effect size (d) and the respective 90% confidence intervals were reported using a modification to the Cohen's effect size scale (Cohen, 1988). The thresholds for Cohen's d effect size statistics were <0.20, trivial; 0.20-0.59, small; 0.60-1.19, moderate; 1.20-1.99, large; and >2.0, very large (Batterham & Hopkins, 2006).

RESULTS

The average physical demand parameters, the most demanding match-play scenarios based on a 1-minute rolling averages and their % difference across playing positions are shown in Table 1. While relative distance presented the lowest % difference (113.1%) of all physical demands for all players, distance covered at high-speed running (>18 km·h^{-1}) and the number of high-speed running actions (>18 km·h-1) returned the greatest variation, with 686.4% and 652.6%, respectively. All physical demands showed significant differences between average values and most demanding 1-minute scenarios, whereas the only significant difference between playing positions was found in the most demanding scenario of high-speed running distance between guards and centres.

Table 1. *Means (±SD) in selected physical demands for average values and the most demanding 1-minute scenarios*

Physical demands parameters	***Positions***	***Averages***	***1-MDS***	***% Difference***
Distance 0 km·h^{-1} (m·min^{-1})	Guards	66.9 ± 9.0 (52.7 – 78.2)	144.3 ± 10.8 (128.2 – 161.6)	115.7
	Forwards	70.2 ± 6.2 (61.2 – 75.6)	142.8 ± 10.1 (133.2 – 154.9)	103.4
	Centres	62.7 ± 6.7 (52.2 – 71.1)	131.4 ± 7.3 (122.0 – 142.1)	109.6
	All players	66.3 ± 8.0 (52.2 – 78.2)	141.3 ± 11.0 (122.0 – 161.6)	113.1
Distance >18 km·h^{-1} (m·min^{-1})	Guards	3.1 ± 1.6 (0.8 – 6.4)	29.4 ± 4.7* (16.5 – 38.2)	848.4
	Forwards	3.7 ± 1.6 (1.4 – 5.0)	25.3 ± 7.7 (17.7 – 35.6)	583.8
	Centres	3.2 ± 0.9 (2.0 – 4.5)	19.3 ± 4.4** (15.2 – 24.4)	503.1
	All players	3.23 ± 1.4 (0.8 – 6.4)	25.4 ± 6.8 (15.2 – 38.2)	686.4
Number >18 km·h^{-1} (n·min^{-1})	Guards	0.4 ± 0.2 (0.1 – 0.8)	3.2 ± 0.9 (2.0 – 5.0)	700.0
	Forwards	0.4 ± 0.1 (0.3 – 0.6)	2.4 ± 0.6 (2.0 – 3.0)	500.0
	Centres	0.3 ± 0.1 (0.1 – 0.5)	2.4 ± 0.9 (2.0 – 4.0)	700.0
	All players	0.4 ± 0.2 (0.1 – 0.8)	2.9 ± 0.9 (2.0 – 5.0)	652.0
Distance accelerations >2 m·s^{-2} (m·min^{-1})	Guards	13.1 ± 4.2 (8.7 – 21.9)	50.5 ± 10.3 (32.5 – 62.5)	285.5
	Forwards	11.6 ± 0.9 (10.1 – 12.4)	53.5 ± 14.5 (40.1 – 74.5)	361.2
	Centres	9.7 ± 3.8 (3.1 – 14.0)	43.3 ± 9.0 31.0 – 54.6)	246.4
	All players	11.8 ± 3.8 (3.1 – 21.9)	49.9 ± 11.1 (31.0 – 74.5)	322.9

***Table 1.** Means (±SD) in selected physical demands for average values and the most demanding 1-minute scenarios*

Physical demands parameters	***Positions***	***Averages***	***1-MDS***	***% Difference***
Distance decelerations $< -2\ m \cdot s^{-2}$ ($m \cdot min^{-1}$)	Guards	9.9 ± 3.2 (5.6 – 15.6)	44.7 ± 5.9 (34.0 – 53.4)	351.5
	Forwards	9.4 ± 2.9 (8.0 – 10.6)	42.9 ± 7.9 (33.4 – 49.2)	356.4
	Centres	9.0 ± 3.1 (3.1 – 12.3)	41.8 ± 8.4 (31.3 – 54.8)	264.4
	All players	9.5 ± 2.8 (3.1 – 15.6)	43.4 ± 6.4 (31.3 – 54.8)	356.8
Number accelerations $> 2\ m \cdot s^{-2}$ ($n \cdot min^{-1}$)	Guards	2.7 ± 1.2 (1.6 – 5.9)	8.4 ± 1.2 (7.0 – 13.0)	211.1
	Forwards	2.6 ± 0.2 (2.1 – 2.7)	9.0 ± 0.7 (8.0 – 10.0)	246.6
	Centres	2.1 ± 0.8 (0.8 – 3.1)	8.6 ± 2.2 (6.0 – 12.0)	309.5
	All players	2.5 ± 1.0 (0.8 – 5.9)	8.8 ± 1.6 (6.0 – 13.0)	252.0
Number decelerations $< -2\ m \cdot s^{-2}$ ($n \cdot min^{-1}$)	Guards	2.6 ± 1.0 (1.03 – 4.7)	8.2 ± 1.6 (5.0 – 12.0)	215.4
	Forwards	2.1 ± 0.3 (1.7 – 2.3)	7.8 ± 1.3 (6.0 – 9.0)	271.4
	Centres	2.1 ± 0.7 (0.8 – 3.1)	8.0 ± 1.2 (7.0 – 10.0)	281.0
	All players	2.1 ± 0.8 (0.8 – 4.7)	8.2 ± 1.6 (5.0 – 12.0)	290.5

Note: 1-MDS is the most demanding 1-minute scenario; Average and the most demanding 1-minute scenarios were significantly different for all physical demand parameters across playing positions. Significant differences (SD) between playing positions are shown as follows: * is SD with centres; and ** is SD with guards.

In addition to significant differences, all player's effect sizes presented very large differences (ES = 3.83 – 7.80) between average physical demands and the most demanding 1-minute scenarios of match-play. Regarding differences between positions, total distance presented large effects between forwards and centres (ES = 1.27) in average values, whereas it also presented large effects between guards and centres (ES = 1.40) and forwards and centres (ES = 1.29) in the most demanding scenarios. Furthermore, guards and centres (ES = 2.22) showed a very large effect in the most demanding scenarios of high-speed running distance.

DISCUSSION

Game activity profiles for elite basketball players based on the traditional average data approach have been reported in previous studies. To the best of our knowledge, this is the first study to provide novel information on the peak physical demands of elite basketball players based on a new approach calculating the most demanding basketball match-play scenarios. These results may help trainers and strength and conditioning coaches to improve evidence-based approaches when designing effective training and rehabilitation interventions. The main finding of the current study reports significant differences (103.4%-848.4%) between the traditional approach based on averages and the most demanding scenarios in all the physical demands examined.

The activity profile during the most demanding scenarios based on 1-minute rolling averages was much more demanding than the activity found using the traditional average method. For example, the results showed that players covered a total distance of 141.3 $m \cdot min^{-1}$ and 25.4 $m \cdot min^{-1}$ at high-speed running using rolling averages compared to 66.3 $m \cdot min^{-1}$, 3.2 $m \cdot min^{-1}$ respectively, using traditional average approach. Moreover, the results showed that players performed 8.8 high-intensity acceleration and 8.2 deceleration actions during the most demanding scenarios, compared to 2.5 and 2.1, respectively, from the traditional averages. These data represent a major increase of 113.1% for the total distance per minute and 686.4% for the high-speed running distance per minute, 252.0% for the number of high-intensity accelerations and 290.5% for the number of high-intensity decelerations, respectively, demonstrating the relevance of this novel approach. The current total distance per minute based on traditional averages was very similar to previous studies reporting ~71 m·min^{-1} of total distance and ~3 m·min^{-1} of high-speed running during official U18 elite games (Pino-Ortega et al., 2019; Vázquez-Guerrero et al., 2019b), measured using LPS systems and 82 m·min^{-1} and 2.5 m·min^{-1} of high-speed running during semi-professional basketball simulated games using GPS (Puente et al., 2017).

A similar tendency has been found in previous research conducted in other team sports, such as soccer (Casamichana et al., 2019; Delaney et al., 2018; Martín-García et al., 2018), Australian football (Delaney et al., 2017), rugby (Cunningham et al., 2018; Delaney et al., 2015) and Gaelic football (Malone et al., 2017)VX Sport, New-Zealand. More specifically, previous research showed that professional football players covered ~180 m·min^{-1} during the most demanding scenarios (Casamichana et al., 2019; Delaney et al., 2018; Varley et al., 2012). In contrast, traditional averages reported of ~100-120 m·min^{-1} covered over a half football match were much lower than peak demands (Bradley & Noakes, 2013). Similarly, Johnston et al. (2014)much of which has involved global positioning system (GPS reported that whole-game relative distances are ~ 94.7 m·min^{-1}, whereas peak demands calculated recently using rolling averages reach between 134 and 166 m·min^{-1} during rugby matches (Cunningham et al., 2018; Weaving et al., 2019). Therefore, overall, these results emphasise that the traditional averages approach underestimates physical demands in team sports, and it may therefore be necessary to complement this approach with this novel insight based on the most demanding scenarios. Consequently, practitioners should ensure that elite-team sport players receive suitable exposure to tactical and technical drills at these peak game requirements during training sessions.

Differences according to playing positions are principally due to the specialisation and specificity of players, how they interact with their teammates or to the needs of competition (Sampaio & Calvo, 2008). An understanding of these differences is crucial to designing and prescribing adequate training sessions for competitive requirements (Reina et al., 2019b). Regarding playing position analysis, centres presented moderately (ES = 0.62, $p < 0.05$) and highly (ES = 1.27, $p < 0.05$) reduced values in total average distance compared to guards and forwards, respectively. Furthermore, the current study also found moderate differences between centres compared to guards (ES = 0.85, $p < 0.05$) and forwards (ES = 0.69, $p < 0.05$) in average distance at high-intensity acceleration. In line with previous research (Pino-Ortega et al., 2019; Vázquez-Guerrero et al., 2019a), minor differences between playing positions were detected in average high-speed running distance. Furthermore, some studies suggested that game location and relative age could influence performance across playing positions differently (Ibáñez et al., 2018; Sampaio & Calvo, 2008). In addition to average physical demands, the most demanding scenarios also showed differences between positions. For instance, guards and forwards covered higher total distances (guards ES = 1.40, $p < 0.05$; forwards ES = 1.29, $p < 0.05$), high-speed running distance (guards ES = 2.22, $p = 0.009$; forwards ES = 0.96, $p < 0.05$) and distance at high-intensity acceleration (guards ES = 0.74, $p < 0.05$; forwards ES = 0.85, $p < 0.05$) compared to centres.

This study is limited because the analysis was conducted in a single game. Although it would also be very interesting to describe the most demanding scenarios during in-season official matches, the Euroleague and the Spanish ACB League do not permit the use of microtechnology during official competition. Furthermore, for technical reasons, this research was not able to determine the effect of ball possession (or not) (i.e. defensive vs offensive game actions). Finally, it would be interesting to know the time-specific appearance of the most demanding scenarios for each physical demand analysed to ascertain if they appear at the same time. Future studies to address these issues are therefore warranted.

In conclusion, this investigation demonstrated that the traditional average method underestimates peak physical demands in a period of at least 1 minute during a basketball game. Thus, it would be recommendable to complement the average approach with an analysis of the most demanding scenarios in order to obtain a better understanding of basketball physical demands. Additionally, we should consider the differences between positions in order to prepare our team according to the specific demands of each role. This information may help trainers and strength and conditioning coaches in training prescription and improve the return to play process.

No potential conflict of interest was reported by the authors

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ESTUDIO 3

AVERAGE GAME PHYSICAL DEMANDS AND THE MOST DEMANDING SCENARIOS OF BASKETBALL COMPETITION IN VARIOUS AGE GROUPS

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Katowice, the 11th of March, 2021

To Whom It May Concern,

On behalf of the Editorial Committee of the *Journal of Human Kinetics*, we would like to confirm that the article entitled "Average game physical demands and the most demanding scenarios of basketball competition in various age groups" by Franc García, Julen Castellano, Xavier Reche, Jairo Vázquez-Guerrero, with the corresponding author Franc García, Sport Performance Area, Futbol Club Barcelona, Barcelona, Basque Country University (UPV/EHU), Physical Activity and Sport, Vitoria-Gasteiz, Spain; has been accepted for print in one of the following issues of the *Journal of Human Kinetics*.

Editor-in Chief

Prof. Adam Zając

ABSTRACT

The purpose of this study was to compare average physical demands and the most demanding 60-s scenarios of basketball match-play between five different age groups. Sixty-four male basketball players from five different age groups were monitored across eight regular-season home games. Physical demands were examined using a local positioning system and included total distance covered, distance >18 km·h^{-1}, the number of accelerations (≥2 m·s^{-2}) and decelerations (≤-2 m·s^{-2}). All four game performance variables increased significantly (58.4 - 639.2%) when calculated with rolling average techniques in comparison to average physical demand values. Furthermore, the current investigation found that while Under-12 presented the highest result in relative total distance covered (*p* <.001; effect size = 0.58-2.01), they also showed the lowest values in the most demanding scenarios of match play and small-to-moderate effect sizes compared with their older counterparts. Both average physical demands and the most demanding scenarios presented an increasing tendency with age when distance >18 km·h^{-1} in basketball players was assessed. More specifically, the Under-12 age group achieved the lowest values and showed significant differences with the other four teams in both game analysis techniques (*p* <.001; effect size = 0.53 - 1.32). In conclusion, average game demands are shown to remarkably underestimate the most demanding scenarios of basketball match-play, and there are multiple significant differences between particular age groups.

KEYWORDS: Team sports, match demands, peak intensity, performance analysis, local positioning system.

INTRODUCTION

Basketball is a high-intensity complex team sport characterized by the interaction of tactical, technical, psychological and physiological components (Stojanović et al., 2018). Multiple explosive jumps, sprints, accelerations, decelerations, and changes of direction based on specific movements such as shooting, rebounding, defending and dribbling are key factors for match-play performance, particularly two-point shots and defensive rebounds (Malarranha et al., 2013). Thus, understanding the physical demands encountered during competition could help strength and conditioning coaches and sport scientists to optimise players' preparation.

Game demands in senior players have been described using video-based movement analysis methodologies (Torres-Ronda et al., 2016), which are based on a subjective visual prediction of the intensity and activity pattern load (Hulka et al., 2014). In addition to the emergence of global positioning systems for outdoor activities (Puente et al., 2017), advances in technology have permitted the use of inertial micro-sensors to quantify physical demands such as high-intensity accelerations and decelerations, among others, in semi-professional (Fox et al., 2018; Scanlan et al., 2019) and professional male basketball players (Svilar et al., 2018; Vázquez-Guerrero et al., 2018) during competition.

While some information is available about physical demands in senior players during games, little is known about youth basketball (Ben Abdelkrim et al., 2010). In addition to video analysis, inertial microtechnology combined with local positioning systems (LPS) have also enabled sports professionals to obtain positional data in U18 players during elite basketball tournaments (Vázquez-Guerrero et al., 2019a, 2019b). Comparisons between game physical demands across different age-groups and senior basketball are important to understand age-specific requirements and adapt the training process. Although understanding the demands placed upon youth players in basketball competition could have practical implications for training prescription and talent identification (Vaeyens et al., 2008), the authors are not aware of any studies that have addressed the physical requirements of elite youth basketball matches across a range of different age groups.

Although the most common method used to analyse player physical exertion during competition has been the study of the average demands, in recent years, state-of-the-art technology has rendered it possible to quantify the most demanding scenarios of match-play in numerous intermittent team sports such as soccer, rugby, Gaelic football and Australian football using different rolling averages (Whitehead et al., 2018). This novel methodology examines the pre-defined time frames, for instance 30, 60 or 120 s, with the greatest demands on any physical variable chosen, namely total distance covered, high-speed running or the number of high-intensity accelerations. Current research using microtechnology has utilized a traditional approach with average values to describe the physical demands of basketball competition (Scanlan et al., 2019; Vázquez-Guerrero et al., 2018, 2019a, 2019b) and to compare physical requirements between match play and training sessions (Fox et al., 2018; Svilar et al., 2018). Nevertheless, the use of average game demands for a training task design could result in under-preparation for the most demanding scenarios of basketball competition (Gabbett et al., 2016), also known in the existing literature as the most demanding passages and worst case scenarios (Martín-García et al., 2018). In addition to improving training, the identification of the most demanding scenarios would also optimise rehabilitation programs geared towards restoring a player's specific fitness and locomotor performance related to the peak physical demands required during match play. To date, the authors are only aware of one preliminary study that has reported the most demanding scenarios during one official basketball game, covering only total distance and player load data (Salazar & Castellano, 2019).

The aim of this study was therefore to compare a traditional average physical demand approach to the most demanding 60-s scenarios (60-MDS) between youth (Under-12, Under-14, Under-16 and Under-18) and senior basketball players during official competition. We hypothesised that 60-MDS values would be significantly higher than average values. Additionally, since physiological characteristics, tactics and competition structure could influence physical demands across age groups, it was also assumed that physical game responses would tend to increase gradually with age. These data are likely to provide an important practical insight for training and game performance optimisation.

METHODS

Participants

The participants in this study were male basketball players (mean ± SD, age: 15.03 ± 2.87 years; body height: 187.2 ± 15.1 cm; and body mass: 75.3 ± 18.2 kg), who belonged to an elite basketball academy of an Euroleague team and competed in five different age groups, classified as Under-12 (U12), Under-14 (U14), Under-16 (U16), Under-18 (U18), and a senior second team (Table 1). Besides the senior team, who participated in the second Spanish professional league (LEB gold), U18, U16, and U14 teams competed at the highest possible regional level. Senior to U14 games were based on FIBA rules, consisting of 4 quarters lasting 10 min, with a 2-min rest period between quarters and a 15-min recovery time between halves. Additionally, the U12 team competed in an older age category, namely the Under-13 (U13) level, according to a modification of the FIBA rules, which were: 1) the ball size was 5; 2) games consisted of eight 5-min periods; 3) all players had to play a minimum of 2 periods and a maximum of 6; 4) player substitutions were only allowed in the last 2 periods. All matches were completed on the same court under similar environmental conditions and players were allowed to consume water ad libitum during rest periods. The five teams usually played one game during the weekend after a standard warm-up protocol that included dynamic stretching, mobility, and basketball-specific individual skill work. In addition, during each microcycle, all five age group teams followed a specific holistic methodology called «structured training», which has been developed by FC Barcelona with the purpose of preparing athletes to compete in team sports (Gómez et al., 2019; Tarragó et al., 2019). This study was performed in accordance with the provisions of the Declaration of Helsinki (Harriss & Atkinson, 2015), and no ethics committee approval was required as the data were obtained routinely during player league games (Winter & Maughan, 2009). Furthermore, players and their parents provided their written consent after the purpose of the investigation and the research protocol along with requirements had been explained to them.

Table 1. *Anthropometry results and training volume according to age*

Group	n	Age (years)	Body height (cm)	Body mass (kg)	Wing-Spam (cm)	Weekly training time (hours)
U12	11	11.2 ± 0.3	167.0 ± 8.0	56.9 ± 11.9	167.6 ± 8.2	4 BP + 1 S&C
U14	14	13.0 ± 0.4	175.3 ± 6.4	60.9 ± 8.9	179.1 ± 7.6	5 BP + 3 S&C
U16	16	15.0 ± 0.5	194.7 ± 7.8	80.1 ± 10.5	200.1 ± 7.6	6 BP + 4 S&C
U18	12	16.8 ± 0.6	198.5 ± 9.3	88.7 ± 13.7	202.8 ± 11.1	7 BP + 4 S&C
Senior	11	19.6 ± 1.5	199.4 ± 9.0	90.5 ± 17.1	201.2 ± 7.9	9 BP + 4 S&C

Note: U12 is the Under-12 age group, U14 is the Under-14 age group, U16 is the Under-16 age group, U18 is the Under-18 age group and senior is the senior team competing in the Spanish professional LEB gold league. BP is basketball practice and S&C stands for strength and conditioning sessions.

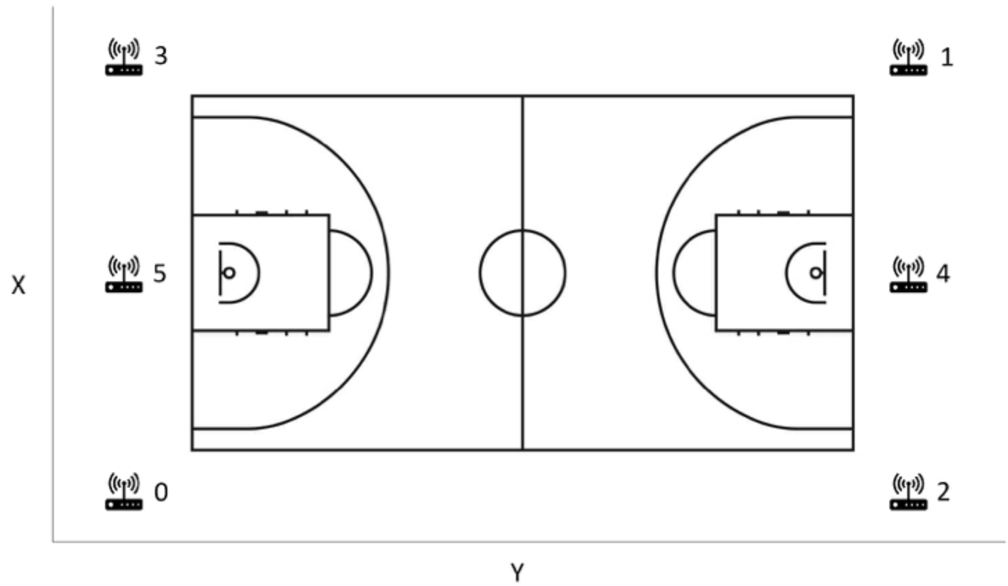
Design and Procedures

The observational design was used to compare physical demands between youth and senior elite basketball using two different methods. Match demands were collected from sixty-four basketball players during eight official home games per age group of the 2018-2019 Spanish competitive basketball season (December-May). Players who completed less than 10 min in a match were excluded, resulting in a total of 344 single records.

Measures

Basketball player movements were monitored during the matches using the WIMU PROć system (Realtrack Systems S.L., Almería, Spain), which has shown good/acceptable accuracy and inter- and intra-unit reliability for ultra-wide band positioning (Bastida-Castillo et al., 2018, 2019) and has been used in previous investigations during basketball competition (Vázquez-Guerrero et al., 2019a, 2019b). The WIMU PRO™ inertial devices (81 x 45 x 16 mm, 70 g) were fitted in a custom vest located on each player's upper back using an adjustable harness, as recommended by the manufacturer (IMAX, Lleida, Spain). The inertial measurement units included four 3-axis accelerometers (100 Hz sample frequency), a gyroscope (100 Hz sample frequency), a 3D magnetometer (100 Hz sample frequency), a barometer, a GPS device (10 Hz sample frequency), and an ultra-wide band positioning system (18 Hz sample frequency). Following the manufacturer's instructions, a total of six antennas were connected, calibrated, and located forming a rectangle to enhance signal emission and reception (Figure 1). Data were downloaded and analysed using the manufacturer's specific software (SPRO™, version 950, RealTrack Systems, Almería, Spain).

Figure 1. *Ultra-wide band positioning system on a basketball court.*



Note: X is court width, y is court length and z is height of the antenna. Numbers show the disposition of antennas in cm: 0 is x = 0, y = 0, z = 600; 1 is x = 2924, y = 5208, z = 600; 2 is x = 0, y = 5208, z = 600; 3 is x = 2928, y = 7, z = 600; 4 is x = 1469, y = 5207, z = 600; and 5 is x = 1456, y = 2, z = 600.

Similar to previous research which used the same physical demand variables to examine U18 basketball competition with the same equipment (Vázquez-Guerrero et al., 2019a, 2019b), four performance variables were selected to monitor player physical demands, such as total distance covered, distance covered >18 $km \cdot h^{-1}$ (high-speed running), and the number of high-intensity accelerations (≥2 $m \cdot s^{-2}$) and decelerations (≤-2 $m \cdot s^{-2}$). While distance was measured via positional differentiation (change in location within each time instant), acceleration was calculated via double differentiation from the positional data recorded by LPS (Malone et al., 2017). To permit comparisons between players with different playing times, all four variables were normalized by the total time spent on the court, excluding only breaks between periods and including all stoppages in play such as free-throws (Vázquez-Guerrero et al., 2019a, 2019b). Consequently, distance values were expressed in $m \cdot min^{-1}$ and the number of accelerations and decelerations in $n \cdot min^{-1}$. Furthermore, 60-MDS during match-play were also analysed using a rolling average over each physical demand variable and only the maximum value for the 60-s time frame was recorded. With sampling of 18 Hz, WIMU PROć software identified 1080 consecutive data points (e.g., 18 samples/s for 60 s) and average values were calculated using the current and the 1060 preceding samples. It is important to note that the 60-MDS for each variable was calculated independently and may have come from different game moments. The 60-s pre-defined time frame choice was justified on the following grounds: 1) the possibility of comparison with average physical demands during competition; and 2) basketball's intrinsic intermittent nature only permits a few continuous match-play periods lasting more than one minute (Salazar & Castellano, 2020).

Statistical Analyses

The descriptive statistics for the outcome measures were calculated using mean and standard deviations. After testing for normality and homogeneity of variances, the t-test was performed to compare average values and 60-MDS. Furthermore, one-way analysis of variance (ANOVA) and Holm post-hoc pairwise comparisons were also performed to detect differences between age groups. All data analyses were performed using R Studio Statistical software (The R Foundation for Statistical Computing, Vienna, Austria) and statistical significance was set at $p < .05$. Additionally, comparison among age groups was assessed via standardised (Cohen) mean differences and their respective 90% confidence intervals (90% CI). Thresholds for effect size (ES) statistics were <0.20, trivial; 0.20-0.59, small; 0.60-1.19, moderate; 1.20-1.99, large; and >2.0, very large (Hopkins et al., 2009).

RESULTS

Total game duration for each age group was as follows: 84.2 ± 5.0 min in seniors; 72.8 ± 11.1 min in U18; 76.2 ± 6.1 min in U16; 74.6 ± 11.3 min in U14; and 64.6 ± 5.0 min in U12. Thus, the average total game duration in youth basketball was lower than senior basketball, namely 13.5% in U18, 9.5% in U16, 11.5% in U14 and 23.4% in U12.

The physical demands for all five age groups examined, and the percentage difference between average values and 60-MDS are shown in Table 2 (means and SD). Furthermore, Figure 1 shows data distribution across age groups, whereas Figure 2 presents significant differences, standardised mean differences and 90% confidence intervals (CI).

Table 2. *Means (±SD) in selected physical demands for the five teams examined*

		U12	U14	U16	U18	Senior
Total distance covered ($m \cdot min^{-1}$)	Average	87.1 ± 6.6	79.8 ± 7.1	79.5 ± 5.5	82.5 ± 8.8	73.9 ± 6.6
	60-MDS	137.7 ± 10.5	144.0 ± 8.8	144.1 ± 9.9	144.6 ± 12.0	140.5 ± 11.6
	% Diff	58.1	80.4	81.2	75.2	90.3
Distance > 18 $km \cdot h^{-1}$ ($m \cdot min^{-1}$)	Average	2.2 ± 1.5	3.0 ± 1.5	3.3 ± 1.5	4.1 ± 1.4	3.3 ± 1.2
	60-MDS	16.0 ± 6.9	20.5 ± 8.1	23.1 ± 7.3	25.4 ± 7.2	23.9 ± 6.2
	% Diff	639.2	589.3	593.7	521.3	622.7
Accelerations > 2 $m \cdot s^{-2}$ ($n \cdot min^{-1}$)	Average	3.9 ± 1.2	3.5 ± 1.0	3.8 ± 1.0	3.8 ± 1.1	3.6 ± 0.9
	60- DS	9.3 ± 2.0	9.3 ± 2.2	10.2 ± 1.8	9.2 ± 2.1	9.2 ± 1.8
	% Diff	136.4	167.9	167.9	143.2	157.1
Decelerations < -2 $m \cdot s^{-2}$ ($n \cdot min^{-1}$)	Average	3.5 ± 1.2	3.1 ± 1.1	3.4 ± 1.0	3.3 ± 1.1	3.2 ± 1.0
	60-MDS	8.7 ± 1.9	8.6 ± 2.3	9.3 ± 1.9	8.7 ± 2.5	8.9 ± 2.2
	% Diff	144.9	174	176.5	160.5	179.4

Note: U12 is the Under-12 age group, U14 is the Under-14 age group, U16 is the Under-16 age group, U18 is the Under-18 age group and senior is the senior team competing in the Spanish professional LEB gold league. 60-MDS are the most demanding 60-s scenarios and % Diff is % difference.

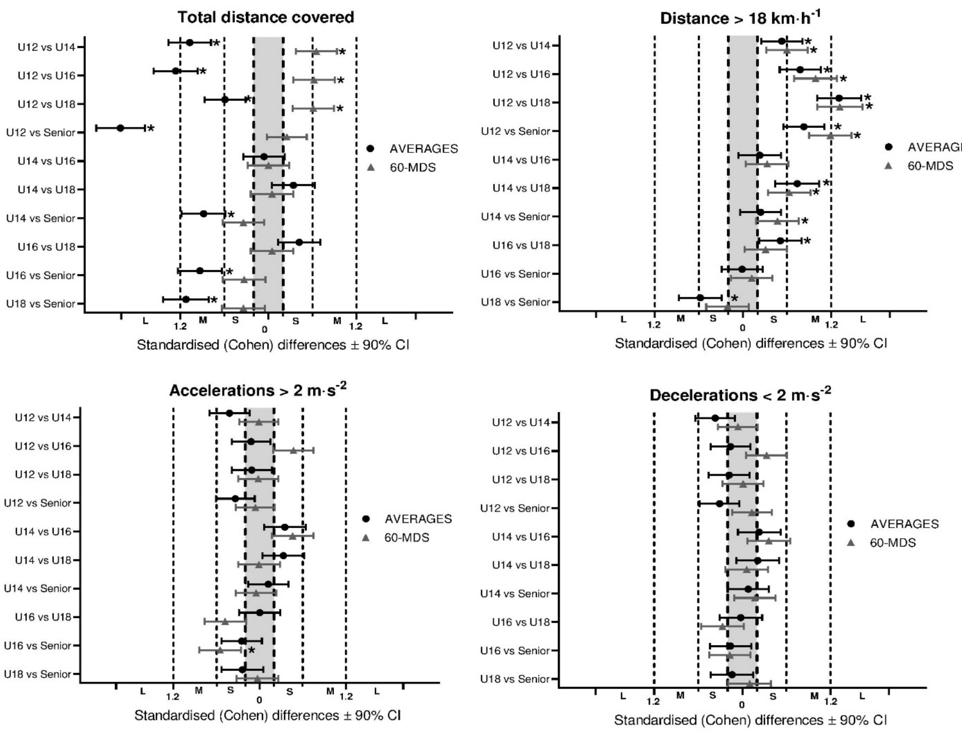
The highest average results in total distance covered were found in the U12 age group, whereas the U18 team achieved the greatest value in 60-MDS. Additionally, the senior team achieved the greatest difference between averages and 60-MDS in total distance covered (90.3%) and the standardised difference between U12 and Senior teams was found to be the only very large effect of all the comparisons. Conversely, the U18 age group presented the highest values in both average and 60-MDS in high-speed running, with a difference of 521.3%. This load variable presented large effects between U12 and U18 in both average and 60-MDS values.

Figure 2. *Density plot between the five teams for the four physical demand variables selected.*

Note: Average and 60-MDS demands were significantly different for all variables and within all age groups. U12 is the Under-12 age group, U14 the Under-14 age group, U16 the Under-16 age group, U18 the Under-18 age group and senior is the senior team competing in the Spanish professional LEB gold league. 60-MDS are the 60-s most demanding scenarios.

High-intensity accelerations and decelerations presented a similar pattern: the highest mean results were achieved by the U12 team, whereas the greatest values in 60-MDS were observed in the U16 age group. Similarly, the differences between averages and 60-MDS ranged from 136.4 to 179.4%. All effect sizes related to high-intensity accelerations and decelerations were trivial to small.

Figure 3. *Standardised differences (Cohen's d) and the 90% confidence intervals between the five teams for the four physical demands variables selected.*



Note: Significant difference is reported with * at the right end of the 90% CI bar. U12 is the Under-12 age group, U14 the Under-14 age group, U16 the Under-16 age group, U18 the Under-18 age group and senior is the senior team competing in the Spanish professional LEB gold league. 60-MDS is 60-s most demanding scenarios.

DISCUSSION

The purpose of this research was to compare the average physical demands and 60-MDS of match-play in different youth age groups and senior basketball players. The main findings of this study were that differences of up to 639.2% between average values and 60-MDS were found. Additionally, total distance covered and high-speed running were significantly different across the teams evaluated using both average and 60-MDS values. These differences may be partly explained by the basketball players' maturation level and team-specific playing models.

Average physical demands and 60-MDS values presented significant differences in all four game performance variables between the five age group teams examined. The present investigation found a greater difference (range = 58.1–90.3%) in total distance covered between average physical demands and 60-MDS than the available research in elite soccer (Varley et al., 2012) and rugby sevens (Furlan et al., 2015), which presented a difference of 25.0% and 38.3% in 5-min and 2-min time intervals used to examine peak demands, respectively. Besides total distance, the high percentage increments in high-speed running (521.3-639.2%) and high-intensity accelerations and decelerations (136.4-179.4%) confirmed that average physical demands substantially underestimated peak requirements during basketball competition. Therefore, knowledge of the upper limit physical demand thresholds during official basketball competition in five different age groups could help basketball professionals enhance training and return-to-play programs, as well as optimise the early talent detection of highly trained young players.

In addition to the differences between the two methodologies, the four performance variables analysed also presented multiple differences between age groups. Conversely to previous research in soccer, in which match running performance showed an increasing trend with age (Buchheit et al., 2010), this study found that relative total distance covered was significantly higher in the U12 team compared to their older counterparts ($p < .001$; U14 ES = 1.07; U16 ES = 1.26; U18 ES = 0.59; Senior ES = 2.01). On the contrary, senior players' relative total distance was significantly lower than in the other four youth teams assessed ($p < .001$; U12 ES = 2.01; U14 ES = 0.88; U16 ES =

0.93; U18 ES = 1.12). Two possible explanations were found: 1) players with greater experience tended to present lower values in physical demands due to better decision-making and game interpretation (Petway et al., 2020); and 2) the total time used to calculate relative values in the current research was higher in senior (9.5 to 23.4%) than youth basketball due to an increased number of game stoppages such as fouls, free throws and time-outs. Besides average physical values, 60-MDS of match-play presented significant differences and moderate effects in total distance between U12 and U14 (ES = 0.65); U12 and U16 (ES = 0.62); and U12 and U18 (ES = 0.61). Particularly, the U12 team presented the lowest values (137.8 ± 10.5 m), which could be attributed to physiological factors since physical capacities were shown to increase with growth (Papaiakovou et al., 2009). Curiously, the senior basketball team did not achieve the highest results during the 60-MDS, which could be accounted for a combination of tactical and game-related factors.

Both average physical demands and 60-MDS presented an increasing tendency with age when high-speed running was evaluated in basketball players. More concretely, the U12 age group achieved the lowest values and showed significant differences with the other four teams in both analysis methodologies. Furthermore, the U14 age group presented lower results compared to the U16, U18 and senior teams. These findings are in agreement with similar studies in soccer which reported a significant improvement in sprint performance between the ages of U14 and U15 (Mujika et al., 2009), probably influenced by maturation. Due to the fact that the average age at the onset of puberty has been suggested as 13.5 years for boys (Stratton et al., 2004), U14 and U12 basketball players may have encountered great difficulties in this study to achieve velocities above >18 km·h^{-1} and accumulate high-speed running distance. Thereby, using fixed speed thresholds would seem to be inappropriate for quantifying high-speed running distance in youth players.

Although total distance and high-speed running demonstrated multiple significant differences and numerous moderate to very large effect sizes between the four age groups and senior basketball, high-intensity accelerations and decelerations presented little variation, with all standardised effect sizes ranging from trivial to small. Following the analysis of these two inertial-derived variables, the U12 team showed the highest average results, which could be explained by their lower game duration, tactical reasons and the modifications of the FIBA rules used. Additionally, 60-MDS presented significant differences in high-intensity accelerations between the U16 age group and the other four teams investigated. Since U18 basketball players have reported peak accelerations up to 3.6 $m \cdot s^{-2}$ during official matches (Vázquez-Guerrero, Jones, et al., 2019c), the use of the 2 $m \cdot s^{-2}$ threshold might have been insufficient to categorize accelerations as high-intensity effort and to identify significant differences between youth and senior basketball players. Therefore, the authors recommend: a) the use of a 3 $m \cdot s^{-2}$ threshold to describe high intensity accelerations, and b) the addition of a qualitative analysis to associate acceleration values with specific basketball actions across different ages.

A potential limitation of the present research is the fact that all teams monitored belonged to the same club and played under the same basketball philosophy. Additionally, the use of fixed thresholds for high-speed running (>18 $km \cdot h^{-1}$) as well as high-intensity accelerations (≥ 2 $m \cdot s^{-2}$) and decelerations (≤ -2 $m \cdot s^{-2}$) could have impaired comparisons between players with different maturation status and physical capacities. Therefore, future investigations should use individualized thresholds for age group comparison. Finally, the exclusive use of the 60-s time period for peak demand assessment could have limited the understanding of the interaction between average physical demands and peak game requirements. To better understand basketball demands, future research should use a wider variety of time intervals during the most demanding scenarios of basketball match-play and examine the correlation of the two above mentioned analyses.

In conclusion, this study demonstrated that average game demands drastically underestimated the most demanding passages of basketball match-play and provided an insufficient approach to coaches for training task prescription. Therefore, the use of rolling techniques would be recommended to find the most demanding scenarios during official competition to establish the upper limit in each load variable and prescribe training accordingly in order to optimise game performance. Furthermore, it its worth mentioning that physical demands are shown to be substantially different between the five basketball age groups investigated, particularly regarding total distance covered and high-speed running.

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CONFLICT OF INTEREST STATEMENT

The authors did not report any potential conflict of interest.

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ESTUDIO 4

COMPARISON OF THE MOST DEMANDING SCENARIOS DURING DIFFERENT IN-SEASON TRAINING SESSIONS AND OFFICIAL MATCHES IN PROFESSIONAL BASKETBALL PLAYERS

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Comparison of the most demanding scenarios during different in-season training sessions and official matches in professional basketball players

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ABSTRACT: The purpose of this study was to compare physical demands during the most demanding scenarios (MDS) of different training sessions and official matches in professional basketball players across playing positions. Thirteen professional basketball players were monitored over a 9-week competitive season using a local positioning system. Peak physical demands included total distance, distance covered at > 18 km·h^{-1}, distance and number of accelerations (≥ 2 m·s^{-2}) and decelerations (≤ -2 m·s^{-2}) over a 60-second epoch. Analysis of variance for repeated measures, Bonferroni post-hoc tests and standardised Cohen's effect size (ES) were calculated. Overall, almost all physical demands during the MDS of training were lower (-6.2% to -35.4%) compared to official matches. The only variable that surpassed competition demands was distance covered at > 18 km·h^{-1}, which presented moderate (ES = 0.61, p = 0.01) and small (ES = 0.48, p > 0.05) increases during training sessions four and three days before a competition, respectively. Conversely, the two previous practices before match day presented trivial to very large decreases (ES = 0.09–2.66) in all physical demands. Furthermore, centres achieved the lowest peak value in total distance covered during matches, forwards completed the greatest peak distance at > 18 km·h^{-1}, and guards performed the greatest distance and number of high-intensity accelerations and decelerations. In conclusion, physical demands during the MDS of different training sessions across the microcycle failed to match or surpass peak values during official matches, which should be considered when prescribing a training process intended to optimise the MDS of match play.

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INTRODUCTION

Basketball is a court-based team sport in which both the aerobic and anaerobic energy systems are highly stressed through a combination of intermittent high-intensity accelerations, decelerations, jumps and sprints based on specific actions such as dribbling, shooting, rebounding or defending [1]. A comprehensive knowledge of the physical demands during basketball competition is crucial for better training load prescription geared towards optimising individual and team performance.

Advances in technology have allowed the use of inertial micro-sensors and local positioning systems to describe physical demands using average values during basketball training and competition [2]. Additionally, microtechnology has helped to compare basketball training sessions and matches, with controversial results regarding which activity produced higher physical exertion [3–6]. Due to the importance of finding the optimal balance between training load and match performance, available research in team sports applying the concept of tapering suggests that physical demand parameters, such as total distance covered and sprints, should be reduced during the training session the day before the match [7, 8]. In this regard, previous research has used microtechnology to examine average physical demands during training and competition loads in the course of in-season microcycles in elite soccer players [8, 9], although it has yet to be analysed in professional basketball players.

Although it is the most common technique, the use of average values to examine players' physical demands to optimise the training process in team sports could result in the underestimation of the most demanding scenarios (MDS) in a match [10], also referred to in the existing literature as most demanding passages and worst-case scenarios [11–13]. More recently, advanced technology has permitted the examination of the MDS during competition in numerous intermittent outdoor team sports [14]. This novel methodology quantifies pre-defined time epochs with the greatest demands on any physical outcome chosen using a rolling average. For instance, available research has reported a 25% difference between average demands and MDS in soccer [10] and 38% in rugby seven [15] in total distance covered using 5-min and 2-min time intervals, respectively. To date, the description of the MDS in a basketball match has only been reported in elite under-18 [16] and semi-professional basketball players [13, 17] with no previous research conducted in professional basketball.

In addition to being useful in studying possible changes in basketball activities, microtechnology has also been used to examine differences in average demands on professional basketball players across specific playing positions during training [18] and competition [19, 20]. Positional roles have also been analysed in elite under-18 basketball players using a rolling average to quantify the MDS [16]. Specifically, Vázquez-Guerrero et al. [16] reported that guards covered a total distance of 123.4 m and accumulated a total of 7.3 accelerations ≥ 2 m·s^{-2} and 6.9 decelerations ≤ -2 m·s^{-2} during a 60-s epoch, whereas forwards and centres covered a total distance of 120 and 113 m and accumulated 6.7 and 6.2 accelerations ≥ 2 m·s^{-2} and 6.1 and 5.3 decelerations ≤ -2 m·s^{-2} during the same 60-s MDS, respectively. To date, the authors are not aware of any studies that have investigated the peak physical demands on professional basketball players across playing positions.

The aim of this study was therefore to compare physical demands during the most demanding 60-second scenarios of different training sessions and official competition in professional male basketball players across playing positions. Knowing these changes in peak physical demands during in-season microcycles could help coaches, athletic performance staff and medical staff to optimise training and match performance.

MATERIALS AND METHODS

Experimental approach to the problem

A nonexperimental, descriptive, comparative design was used to examine the differences between the MDS of training and competition across playing positions. Local positioning system data were collected from 17 competitive league matches and 39 training weeks in the 2018–19 season. However, this study only included for further analysis the 9 in-season weeks in which players had six days between competitive matches and involved a minimum of four training sessions with a clear focus on an upcoming official league match. All competitive matches and training sessions were completed on the same official basketball court in similar environmental conditions. Players were excluded from the study if they completed less than 5 training sessions and did not participate in any competitive match. Furthermore, players who did not finish a full training session or those who played less than 10 min in a match were also excluded, resulting in a total of 428 individual observations. Table 1 shows the duration of each training session and match completed during in-season weeks and the total number of single records across a training session or match and the three different playing positions: guards (n = 7), forwards (n = 3) and centres (n = 3). As a working hypothesis, it was assumed that official matches would present peak values significantly higher than training sessions across all playing positions.

Participants

The thirteen professional male basketball players (mean ± SD, age: 19.8 ± 1.7 years; height: 199.9 ± 8.2 cm; and body mass: 91.8 ± 15.9 kg) who participated in this research belonged to a reserve squad of a Spanish Euroleague team and competed in the Spanish second division (LEB Oro). Players were routinely monitored during all training sessions and matches in the course of the competitive season, so no ethics committee approval was needed [21]. Nevertheless, the study fulfilled the provisions of the Declaration of Helsinki [22] and all the players agreed to participate by providing their written consent.

Training periodisation

The structured microcycle is the basic organization in the holistic structured training methodology of Futbol Club Barcelona [23, 24], which has been developed with the purpose of preparing athletes to

TABLE 1. The duration (means ± SD) and total of individual observations across different session types and playing positions.

Session	Duration (min)	Guards	Forwards	Centres	All positions
MD-4	109.4 ± 14.5	36	24	17	77
MD-3	128.6 ± 32.2	43	23	21	87
MD-2	109.3 ± 22.2	44	24	20	88
MD-1	87.9 ± 16.8	46	24	19	89
MD	109.3 ± 7.6*	41	26	20	87

Note: MD-4 is match day minus four; MD-3 is match day minus three; MD-2 is match day minus two; MD-1 is match day minus one; and MD is match day. * MD duration includes all stoppages in match, such as time-outs and free throws and breaks between periods, which are 3 min between the first and second quarter and between the third and fourth quarter, and 15 min between the second and third quarter.

TABLE 2. General goals and specific training contents across the structured microcyle in basketball

Session	Goals	Contents
MD-4	General goal	To develop basketball players' basic skills
	Coadjuvant training	Structural
	Optimizing training	Individual skills, small sided matches and modified 5-on-5 drills
MD-3	General goal	To accumulate the highest weekly basketball-specific load and optimise the team's playing model
	Coadjuvant training	Specific qualities
	Optimizing training	Simulated 5-on-5 competition
MD-2	General goal	To develop specific speed in basketball
	Coadjuvant training	Group preventive
	Optimizing training	Half-court 5-on-5 plus 1 or 2 waves
MD-1	General goal	To prepare players tactically for the next match
	Coadjuvant training	Individual preventive
	Optimizing training	Moderate-intensity drills and half-court 5-on-5
MD	General goal	To physically and mentally activate players
	Coadjuvant training	Individual preventive
	Optimizing training	Walk-through 5-on-5 and positional shooting drills

Note: MD-4 is match day minus four; MD-3 is match day minus three; MD-2 is match day minus two; MD-1 is match day minus one; MD is match day (light-load non-monitored training session on the morning).

compete in team sports and is based on two types of training: coadjuvant (general off-court training) and optimising (sport-specific, on-court training) [25, 26]. Based on the recommendations of Akenhead et al. [9], the MDS of training sessions were examined with respect to the number of days before an official match (MD minus). In line with Martín-García et al. [8], physical, technical and tactical components were integrated in all training sessions, which were contextualised in Table 2.

Physical demand parameters

Similar to previous research [14, 16], total distance covered in metres, distance covered at > 18 $km \cdot h^{-1}$ in metres, distance at high-intensity acceleration (≥ 2 $m \cdot s^{-2}$) and deceleration (≤ -2 $m \cdot s^{-2}$) in metres, and number of high-intensity accelerations (≥ 2 $m \cdot s^{-2}$) and decelerations (≤ -2 $m \cdot s^{-2}$) were measured. The analysis of the MDS consisted of identifying the peak physical demands for each player and each outcome mentioned above during each training and match session using a rolling (or moving) average over a 60-second epoch. With a local positioning system (WIMU PRO, RealTrack Systems S.L., Almería, Spain) that includes ultra-wide band technology (18 Hz sample frequency), the brand-specific software identified 1080 consecutive data points (e.g., 18 samples/s for 60 s) and rolling average values were calculated using the current and the 1062 preceding samples. It is important to note that the MDS for each variable was calculated independently and may have come from different game moments. The results show the average values of MDS during basketball training and match play and the 60-s pre-defined epoch was chosen because it has already been used in previous research and, moreover, it facilitates comparisons with average physical demands [13, 17, 27].

Procedures

Player movements during training and matches were recorded using a local positioning system (WIMU PRO, RealTrack Systems S.L., Almería, Spain). Based on the manufacturer's recommendations, the tracking units were placed in a custom-made vest located in the centre of the upper back using an adjustable harness (IMAX, Lleida, Spain). These inertial devices (81x45x16 mm, 70 g) include four 3D accelerometers (full-scale output ranges are ± 16 g, ± 16 g, ± 32 g, ± 400 g, 100 Hz sample frequency), a gyroscope (8000º/s full-scale output range, 100 Hz sample frequency), a 3D magnetometer (100 Hz sample frequency), a GPS (10 Hz sample frequency) and an ultra-wide band positioning system (18 Hz sample frequency). Furthermore, each unit has an 8 GB flash memory, a gigahertz microprocessor and a high-speed USB interface to record, store and upload data. This ultra-wide band positioning system includes six antennas, three of them placed 12 metres away from each baseline of the basketball court. For better signal emission and reception, antennas were located forming a rectangle at a height of seven and half metres above the wooden floor and 17 metres apart. WIMU PRO has been shown to have good/acceptable accuracy and inter- and intra-unit reliability for ultra-wide band positioning in indoor sports [28]. Data were downloaded and analysed using the system-specific software (SPRO, version 955, RealTrack Systems, Almería, Spain).

Statistical analysis

Descriptive statistics data are presented using means, SD (± SD) and difference percentage. The data were analysed using an analysis of variance (ANOVA) for repeated measures and Bonferroni post-hoc tests. Statistical analyses were performed using JASP v0.9.2 software (University of Amsterdam, https://jasp-stats.org/) and the statistical significance was set at $p \leq 0.05$. Furthermore, differences between the training sessions and the corresponding official basketball matches by playing positions were examined using standardised (Cohen's d) mean differences and their respective 90% confidence intervals (90% CI). Thresholds for effect size (ES) statistics were < 0.20, trivial; 0.20–0.59, small; 0.60–1.19, moderate; 1.20–1.99, large; and > 2.0, very large [29].

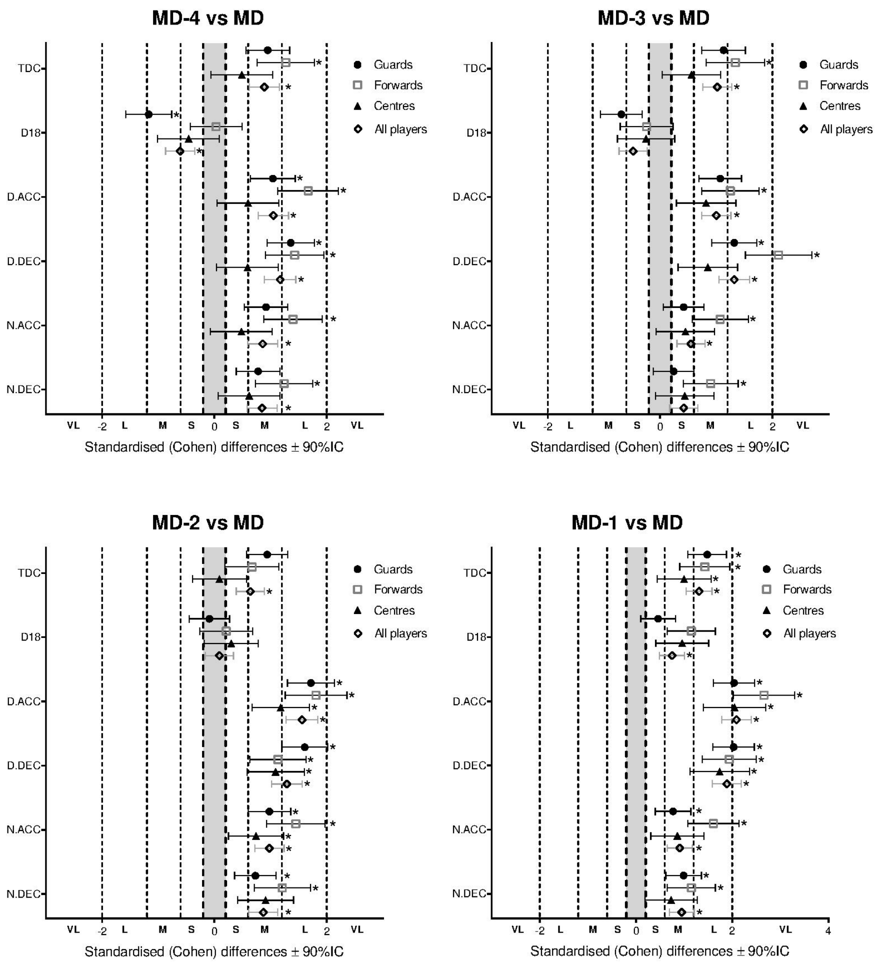

FIG. 1. Standardised differences (Cohen's d) and the 90% confidence intervals for the most demanding scenarios during 60-s epochs. Note: Significant difference is reported with * at the right end of the 90% CI bar. MD-4 is match day minus four; MD-3 is match day minus three; MD-2 is match day minus two; MD-1 is match day minus one; MD is match day; TDC is total distance covered in metres; D18 is distance covered at > 18 $km \cdot h^{-1}$ in metres; D.ACC is distance at high-intensity acceleration (≥ 2 $m \cdot s^{-2}$) in metres; D.DEC is distance at high-intensity decelerations (≤ -2 $m \cdot s^{-2}$) in metres; N.ACC is number of high-intensity accelerations (≥ 2 $m \cdot s^{-2}$); N.DEC is number of high-intensity decelerations (≤ -2 $m \cdot s^{-2}$); VL is very large effect; L is large effect; M is moderate effect; S is small effect.

TABLE 3. Physical demands parameters of the most demanding 60-second scenarios for professional basketball players across playing positions.

Physical Demand Parameter	Playing Position	MD-4		MD-3		MD-2		MD-1		MD
		Means (SD)	% Diff	Means (SD)	% Diff	Means (SD)	% Diff	Means (SD)	% Diff	Means (SD)
Total distance covered (m)	Guards	128.0 ± 16.6	-9.2	125.6 ± 16.5	-10.9	126.8 ± 18.9	-10.0	118.2 ± 19.4	-16.1	140.9 ± 9.8
	Forwards	122.4 ± 17.1	-12.4	121.5 ± 16.9	-13.0	131.2 ± 15.8	-6.2	116.6 ± 20.9	-16.6	139.8 ± 9.2
	Centres	119.9 ± 20.3	-6.3	119.8 ± 17.4	-6.3	126.5 ± 19.8	-1.1	110.7 ± 21.9	-13.4	127.9 ± 10.5
	All players	124.4 ± 17.7	-9.6	123.1 ± 16.8	-10.5	127.9 ± 18.2	-7.0	116.2 ± 20.3	-15.6	137.6 ± 11.1
Distance > 18 km·h^{-1} (m)	Guards	31.3 ± 9.2	**+46.3**	30.1 ± 16.0	**+40.7**	22.1 ± 7.9	**+3.3**	17.3 ± 10.0	-19.2	21.4 ± 7.7
	Forwards	24.8 ± 10.3	-1.2	27.7 ± 13.2	**+10.4**	23.3 ± 10.1	-7.2	16.4 ± 8.0	-34.7	25.1 ± 7.2
	Centres	27.3 ± 10.5	**+18.2**	25.1 ± 8.6	**+8.7**	21.1 ± 5.5	-8.7	15.3 ± 8.8	-33.8	23.1 ± 7.5
	All players	28.4 ± 10.1	**+24.0**	28.2 ± 13.8	**+23.1**	22.2 ± 8.1	-3.0	16.6 ± 9.2	-27.5	22.9 ± 7.6
Distance at acceleration ≥ 2 m·s^{-2} (m)	Guards	40.4 ± 8.5	-17.9	40.8 ± 7.3	-17.1	34.6 ± 8.6	-29.7	31.2 ± 9.2	-36.6	49.2 ± 8.4
	Forwards	34.2 ± 7.7	-28.6	35.8 ± 10.5	-25.3	32.4 ± 8.4	-32.4	27.5 ± 6.4	-42.6	47.9 ± 8.7
	Centres	36.2 ± 11.8	-15.6	34.2 ± 10.6	-20.3	31.3 ± 9.0	-27.0	25.0 ± 6.2	-41.7	42.9 ± 10.6
	All players	37.5 ± 9.4	-20.7	37.9 ± 9.5	-19.9	33.3 ± 8.6	-29.6	28.9 ± 8.3	-38.9	47.3 ± 9.3
Distance at deceleration ≤ -2 m·s^{-2} (m)	Guards	33.1 ± 7.8	-25.1	34.1 ± 6.8	-22.9	31.2 ± 7.7	-29.4	26.9 ± 8.6	-39.1	44.2 ± 8.4
	Forwards	31.1 ± 7.9	-25.6	27.0 ± 7.0	-35.4	30.3 ± 12.6	-27.5	25.2 ± 9.9	-39.7	41.8 ± 7.0
	Centres	32.7 ± 8.3	-13.9	30.9 ± 6.8	-18.7	28.6 ± 7.4	-24.7	23.2 ± 7.1	-38.9	38.0 ± 9.7
	All players	32.4 ± 7.9	-23.0	31.5 ± 7.4	-25.2	30.6 ± 9.2	-27.3	25.7 ± 8.7	-39.0	42.1 ± 8.6
Accelerations ≥ 2 m·s^{-2} (counts)	Guards	8.4 ± 2.4	-20.0	9.6 ± 2.1	-8.6	8.2 ± 2.5	-21.9	8.4 ± 3.2	-20.0	10.5 ± 2.2
	Forwards	7.5 ± 1.1	-25.7	7.78 ± 1.9	-23.0	7.3 ± 1.3	-27.7	6.8 ± 1.6	-32.7	10.1 ± 2.4
	Centres	8.5 ± 2.5	-14.1	8.6 ± 2.3	-13.1	7.6 ± 2.9	-23.2	7.4 ± 2.5	-25.3	9.9 ± 3.3
	All players	8.2 ± 2.1	-19.6	8.9 ± 2.2	-12.7	7.8 ± 2.4	-23.5	7.8 ± 2.8	-23.5	10.2 ± 2.5
Decelerations ≤ -2 m·s^{-2} (counts)	Guards	8.2 ± 2.2	-17.5	9.3 ± 2.7	-6.1	8.1 ± 2.7	-18.2	7.5 ± 2.6	-24.2	9.9 ± 2.3
	Forwards	6.7 ± 1.9	-29.8	7.4 ± 2.0	-22.1	6.8 ± 1.8	-28.4	6.7 ± 2.3	-29.5	9.5 ± 2.6
	Centres	8.0 ± 2.1	-17.5	8.4 ± 2.5	-13.4	7.1 ± 2.3	-26.8	7.6 ± 2.4	-21.6	9.7 ± 3.3
	All players	7.7 ± 2.2	-21.0	8.6 ± 2.6	-11.3	7.5 ± 2.4	-22.7	7.3 ± 2.5	-24.7	9.7 ± 2.6

Note: % Diff is percentage of difference between training and competition; bolded % Diff shows differences where training values are higher than competition; MD-4 is match day minus four; MD-3 is match day minus three; MD-2 is match day minus two; MD-1 is match day minus one; and MD is match day.

RESULTS

Descriptive values for the MDS of different training sessions and official basketball matches across playing positions are presented in Table 2. The results revealed that distance covered at > 18 km·h^{-1} was the only physical parameter in which players achieved higher peak values during training sessions compared to official competition. More particularly, differences between MDS during the MD-3 preparatory session and matches ranged between +8.7% and +40.7%. In contrast, the other five variables showed the highest MDS values during matches, and the lowest differences were found in the MD-4 and MD-3 sessions. Furthermore, the MD-1 session presented the lowest values in all physical variables and the largest MDS differences with MD across playing positions (-13.4% to -42.6%).

Figure 1 shows ES and statistical differences between the four different training session types (MD-4, MD-3, MD-2 and MD-1) and official matches (MD) across playing positions. MD-4 and MD-3 sessions presented a similar pattern: while distance covered at > 18 km·h^{-1} showed small to moderate increases during training sessions, the other five physical demands parameters showed small to very large MDS decreases in comparison to MD. More particularly, the largest decrease (ES = 2.11) was found in the forward position for the distance at high-intensity decelerations during the MD-3 training type. In contrast to distance covered at > 18 km·h^{-1} during MD-4 and MD-3, all six physical demand parameters presented lower values of MDS with a decreased tendency during MD-2 and MD-1 compared to official matches. By way of example, distance at high-intensity acceleration and deceleration presented moderate to large decreases in MD-2, whereas large to very large decreases were observed in MD-1 compared to MD. Moreover, the forward position presented the greatest difference (ES = 2.66) in distance at high-intensity acceleration between MD-1 and MD.

DISCUSSION

The purpose of this study was to examine the MDS in basketball training and competition across playing positions. The main finding of this research was that 60-second peak values for the majority of the physical demand parameters examined were higher during official matches than training for any basketball playing position. Nevertheless, distance covered at > 18 km·h^{-1} was the only load variable that was greater than MD-4 (ES = 0.61, $p = 0.01$) and MD-3 (ES = 0.48, $p > 0.05$) preparation sessions in all players compared to MD. Therefore, athletic staff and basketball coaches should consider using the MDS of match play to examine the relationship between training and competition in order to optimise individual physical performance.

In contrast to this study, showing overall higher physical demands in the MDS of basketball match play, available research has reported greater average accelerometer-derived values during training compared to competition in male basketball players [4, 5]. However, the work in question examined back-to-back pre-season friendly matches, which may not replicate official match demands because coaches may consider these sessions to be preparatory and players are not competition-fit. Furthermore, the use of average physical demands could also explain the results, since inactivity periods during training (e.g. coaching instruction) could be longer and more frequent than during matches (e.g. free-throws and substitutions), which would limit the occurrence of greater MDS [30]. Nevertheless, this limitation could be resolved by excluding or reducing rest periods and using a rolling average for MDS identification. Similar to this research, Fox et al. [17] found greater peak values during official matches than training with moderate to large differences across six different time epochs ranging from 0.5 to 5 minutes. The so-called "effort rationale" term might justify the higher physical demands values during regulated basketball matches because of the involvement of real opponents, fans and their consequent motivation and focus [4].

When comparing the different types of basketball training sessions, MD-4 and MD-3 present the highest MDS results. Moreover, their increased total training volume (Table 1) and the priority for high-specificity drills such as 5-on-5 simulated matches show that they should be regarded as high-load training sessions. However, a total of five physical demand parameters, i.e. total distance covered, distance at high-intensity acceleration and deceleration, and number of high-intensity accelerations and decelerations, failed to match or surpass the match's peak values. Specifically, this study found moderate to large differences in total distance covered (ES MD-4 = 0.89, $p < 0.001$; ES MD-3 = 1.02, $p < 0.001$), and distance at acceleration (ES MD-4 = 1.05, $p < 0.001$; ES MD-3 = 1.00, $p < 0.001$) and deceleration (ES MD-4 = 1.17, $p < 0.001$; ES MD-3 = 1.32, $p < 0.001$) with physical demand values ranging from -9.3% to -23.0% below the MDS of match play for all playing positions. Conversely, the only load variable examined that surpassed competition demands was distance covered at > 18 km·h^{-1}, which presented moderate (ES = 0.61, $p = 0.01$) and small (ES = 0.48, $p > 0.05$) increases during MD-4 and MD-3, respectively. The fact that only distance covered at > 18 km·h^{-1} was overloaded during training sessions shows that MD-4 and MD-3 contained a minimum of one drill in which players were forced to run several times from baseline to baseline at high speed, accumulating several metres at > 18 km·h^{-1}. Although this study could not identify the specific basketball tasks in which the MDS were found, these results suggest that the preparatory drills proposed during MD-4 and MD-3 did not match the physical demands in the most intense periods of official competition.

In contrast to MD-4 and MD-3, MD-2 and MD-1 presented a progressive reduction in training volume (Table 1) and a small to very large reduction in the MDS during sessions. These values are in line with previous studies in different team sports [7, 8], in which coaches tend to reduce physical demand parameters the day(s) before a competition following a tapering strategy to allow enough recovery time before the upcoming match. However, available research in professional female basketball players did not reveal significant differences in average values of an accelerometer-derived variable between three training sessions before difficult matches using inertial microsensors [31]. In addition to match difficulty, caution should be exercised with recommendations about stressing the most intense periods of training-play during MD-2 and MD-1, since this study investigated peak values instead of average physical demands.

Although playing positions showed trivial to small differences during the MDS of training in relation to MD, this study obtained comparable results to previous research using peak values to examine physical demands in sub-elite basketball players [16]. In particular, Vázquez-Guerrero et al. [16] concluded that centres achieved the lowest MDS results in total distance covered, forwards and guards completed the greatest high-intensity running (18.1–24.0 km·h^{-1}), and guards performed the highest number of, and covered the greatest distance in, high-intensity accelerations (≥ 2 m·s^{-2}) and decelerations (≤ -2 m·s^{-2}) in under-18 basketball players monitored during official tournament matches. Similarly, this research showed that centres obtained the lowest peak value in total distance covered during MD, which could be related to this position remaining near the three-second zone in more static positions for tactical reasons. Furthermore, although the available research has shown that centres can complete the greatest distances at above 18 km·h^{-1} [19], this investigation found that forwards presented the greatest MDS of match-play in distance covered at > 18 km·h^{-1}, which could be attributed to the fact that forwards are shorter and have a lower body mass than centres [32] and seem to be better prepared to achieve higher results during the most demanding 60-second scenarios. Finally, this study also concluded that the highest values of MDS in distance and number of high-intensity accelerations and decelerations are found in guards, followed by forwards and centres. In addition to the rationale that smaller players require less force to achieve the same or higher accelerations due to their lower body mass [18], this

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ESTUDIO 5

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The Most Demanding Scenarios of Play in Basketball Competition From Elite Under-18 Teams

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The main purpose of this study was to describe the most demanding scenarios of match play in basketball through a number of physical demand measures (high-intensity accelerations and decelerations, relative distance covered, and relative distance covered in established speed zones) for four different rolling average time epochs (30, 60, 180, and 300 s) during an official international tournament. A secondary purpose was to identify whether there were significant differences in physical demand measures among playing positions (centers, guards, and forwards) and levels (two best classified teams in the tournament and remaining teams), match scoring (winning, losing, and drawing), and playing periods (match quarter) at the moment of the most demanding scenarios. Data were collected from 94 male under 18 (U18) elite basketball players (age: 17.4 ± 0.7 years; stature: 199.0 ± 11.9 cm; body mass: 87.1 ± 13.1 kg) competing in a Euroleague Basketball Tournament. Measures were compared via a Bayesian inference analysis. The results revealed the presence of position-related differences [Bayesian factor (BF) > 10 (at least strong evidence) and standardized effect size (δ) > 0.6 (at least moderate)] so that centers covered a lower relative distance at speed zone 1 and had lower high-intensity accelerations and decelerations than guards. However, the Bayesian analysis did not demonstrate the existence of significant differences in any physical demand measure in relation to the playing level, match scoring, and playing periods at the moment of the most demanding scenarios. Therefore, this study provides coaches and strength and conditioning specialists with a most demanding scenario reference on physical demands that can be used as an upper limit threshold in the training and rehabilitation monitoring processes.

Keywords: worst-case scenario, movement demands, game analysis, inertial movement sensors, team sport

INTRODUCTION

Basketball is an intermittent, court-based team sport that requires players to perform a substantive number of repeated high-intensity movements such as accelerations and decelerations, changes of direction, high-speed running, jumping, and landing (Ostojic et al., 2006; Scanlan et al., 2011). Therefore, a fundamental task for coaches and strength and conditioning specialists is the design, implementation, and monitoring of training programs that allow them

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to ensure that basketball players are prepared to deal with the high-intensity periods of match play. Accordingly, the study of players' physical demands using variables like distance covered at different speeds (walking and jogging, high-speed running, sprinting) and the number of high-intensity actions executed (accelerations and decelerations) during match play has been one of the most common research topics in the last decades (Klusemann et al., 2013; Fox et al., 2018; Svilar et al., 2018; Vázquez-Guerrero et al., 2019).

State-of-the-art microtechnology allows monitoring players' locomotor movements and fosters the development of novel approaches to study sports performance based on the identification of the most demanding passages or scenarios of match play (also called worst-case scenarios) using different rolling average time durations. In particular, a novel approach has been recently suggested to describe the most demanding scenarios of match play through the use of the "peak scores" of relevant (in terms of sport performance) physical demand measures after having examined second by second all their scores using rolling average time epochs (e.g., 0–3, 1–4, 2–5 min). Some studies have demonstrated that the use of the traditional sequential (also called fixed-length or discrete time epochs) approach to calculate physical demands based on average values (e.g., 0–3, 3–6, 6–9 min) underestimates the periods of maximum exigence (up to ∼25%) in intermittent sports, when compared to the novel rolling average time epoch approach, due not only to its inability to capture fluctuations in physical demands but also to issues of reduced sampling resolution associated with using pre-defined fixed-time epochs (Varley et al., 2012; Furlan et al., 2015). For example, whether the most demanding scenario of a particular physical demand measure occurred between 2 and 5 min during competitive match play, the use of the traditional segmental analysis that take averages from 0–3 and 3–6 min would miss the full peak period, and this consequently would lead to an underestimation of this physical demand measure (Whitehead et al., 2018). These observed differences in players' physical demands between the sequential and rolling average time epoch approaches seem to increase as the time epoch length decreases (i.e., below 5 min), which may be due to the physiological, contextual, and technical–tactical demands of the sport (Ly et al., 2016; Wagenmakers et al., 2018). Furthermore, it has been also suggested that the higher the sample frequency is, the larger the inter-approach differences may be (Doncaster et al., 2019).

Therefore, this new rolling average time epoch approach, unlike the studies reporting the average physical demands of match play, may provide greater insight into the requirements on players during the most intense active phases of matches. In terms of practical applications, knowing the most demanding scenarios of match play in intermittent team sports may be especially relevant for the development of ecologically valid physical stimuli during training drills that ensure that players are appropriately prepared for the most demanding periods (in terms of physical demands) of match play (Gabbett et al., 2012; Gabbett, 2016; Tierney et al., 2017). Likewise, the characterization of the most demanding scenarios in physical demands of match play might also improve the rehabilitation programs due to the fact that restoring players' specific fitness and locomotor performance in relation to match physical demands may be a primary return-to-play criterion from a sport-related injury (Buchheit and Mayer, 2018).

While some studies have determined the most demanding scenarios in physical demands during competition in intermittent team sports such as association football (Abbott et al., 2018; Delaney et al., 2018; Martín-García et al., 2018; Casamichana et al., 2019), rugby (Delaney et al., 2016; Cunningham et al., 2018), Gaelic football (Malone et al., 2017), and Australian football (Delaney et al., 2017) through different time average rolling durations, no studies are available that quantify physical demands during match play in basketball using this approach. A plethora of studies have examined the average (mainly per minute) and absolute physical demands of match play in basketball reporting that players usually cover 5–6 km at an average speed of 70–90 m min^{-1} and perform a total of 40–50 jumps (Stojanović et al., 2018). Furthermore, most of these studies have also identified that the physical demands experienced by players during basketball match play are influenced by the playing positions and levels, whereby guards and top players sustain greater workloads than forwards, centers, and lower-level players at the same positions. However, as stated before, the utility of this information to develop appropriate training programs to optimize physical preparedness for competition may be limited.

Therefore, the main purpose of this study was to describe the most demanding scenarios of match play in basketball through a number of physical demand measures for four different rolling average time epochs (30, 60, 180, and 300 s) during an official U18 international tournament. A secondary purpose was to identify whether there were differences in physical demands among playing positions (centers, guards, and forwards) and levels (two best classified teams in the tournament and remaining teams), match scoring (winning, losing, and drawing), and playing periods (match quarter) at the moment of the most demanding scenarios.

MATERIALS AND METHODS

Participants

A total of 94 male (under 18) elite basketball players (age: 17.4 ± 0.7 years; stature: 199.0 ± 11.9 cm; body mass: 87.1 ± 13.1 kg) from eight teams and six countries competing in the 2017 edition of the Euroleague Basketball Next Generation Tournament participated in the current study. Players were grouped according to their playing position as centers (*n* = 17), guards (*n* = 35), and forward (*n* = 42) (Abdelkrim et al., 2010a,b). Playing positions were first determined by the information available on the Euroleague website and further refined by a qualified basketball coach (i.e., level 3 certificate in coaching basketball from the Spanish Basketball Federation with more than 5 years of experience coaching teams in top national leagues). Before any participation, experimental procedures and potential risks were fully explained to both players and coaches in verbal and written forms, and written informed consent was obtained from them. The experimental procedures used in this study were in accordance with the Declaration of Fortaleza and were approved by the local Ethics and Scientific Committee.

Procedures

A descriptive study design was used to address the purposes of this study. All 13 matches from the tournament were monitored over the 4-day schedule. The matches were played on the same court in similar environmental conditions at different times of the day according to the official schedule and using International basketball federation official rules. Matches started with a 15 min warm-up. During each match play, all the players were continuously monitored, but the physical demands were quantified only when players were competing on court (e.g., when a player was a substitute or when there was a rest time between quarters, this was not included). All players were not required to follow any previous dietary recommendation or restriction, but they were able to replace water loss by drinking *ad libitum* during the game recovery periods.

Players' data were included for analysis provided they did not suffer injury during the match, played in the same position throughout the match, and played at least 5 min of live time in each match (Sampaio et al., 2006, 2010).

Players' movements were measured using a portable local positioning system (LPS) (WIMU PRO®, Realtrack Systems SL, Almería, Spain) during matches. Devices (81 mm × 45 mm × 15 mm, 70 g) were fitted to the upper back of each player using an adjustable harness (Rasán, Valencia, Spain). The WIMU PRO units integrate different sensors registering at different sample frequencies. Sampling frequency for a three-axis accelerometer, gyroscope, and magnetometer was 100 Hz and 120 kPa for the barometer. The system has six ultra-wide-band antennas, four placed 3 m outside the corners of the court and two placed 3 m outside half-court; the sampling frequency for positioning data was 20 Hz. The system operates using triangulations between the antennas and the units; the six antennas send a signal to the units every 50 ms. Then, the device calculates the time required to receive the signal and derives the unit position (coordinates x and y), using one of the antennas as a reference.

WIMU PRO® software was used for the computation of rolling averages over each physical demand measure of interest using four different time epochs (30, 60, 180, and 300 s), and the maximum value for each time epoch was recorded. For example, for a 60 s rolling average with a sampling of 20 Hz, the software identified 1,200 consecutive data points (i.e., 18 samples/s for 60 s). For a 120 s rolling average, 2,400 samples were used, and so on. Thus, for the 60 s rolling epoch, algorithm values were calculated using the current and the 1,180 preceding samples. A similar procedure was followed for the four different time epochs selected.

In each time epoch, the peak values of the physical demand measures selected were recorded independently, so that it is very likely that they came from different data points. The rationale behind the selection of the 30, 60, and 180 s time epochs was based on the findings shown by previous studies that report that: a) approximately 90% of the live-time actions in basketball match play have a duration lower than 80 s (of which around 17 and 26% exhibited a duration near 30 and 60 s, respectively) and b) actions with durations longer than 180 s are very unlikely (Conte et al., 2016; Zhang et al., 2019). Time frames shorter than 30 s were considered too short from a task design perspective and consequently were discarded.

Although the 300 s time epoch does not represent the most common durations of the actions that characterize the game of basketball, it was finally selected because after having spoken with several coaches and strength and conditioning specialists, most of them agreed that this duration may represent the time that several players are on court during basketball match play before being substituted or a time-out is provided. Therefore, describing the most demanding scenarios in physical demands during competition using this wide time epoch also might be useful to know the peak physical demands that a player usually has to address before a stoppage time phase higher than 40 s is given.

Therefore, for each match play, maximum values using 10 physical demand measures were calculated for each time epoch. In particular, the following physical demand variables were measured and reported: (a) relative distance (total distance/playing duration); (b) relative distance in established speed zones [zone 1: stationary/walking ($<$6.0 km h^{-1}), zone 2: jogging (6.0–12.0 km h^{-1}), zone 3: running (12.1–18.0 km h^{-1}), zone 4: high-intensity running (18.1–24.0 km h^{-1}), and zone 5: sprinting ($>$24.0 km h^{-1})]; c) high-intensity accelerations ($>$2 m s^{-2}) and decelerations ($<$-2 m s^{-2}); and f) distance covered at high-intensity accelerations ($>$2 m s^{-2}) and decelerations ($<$-2 m s^{-2}). The speed and movement zones selected were similar to those used in other basketball studies (McInnes et al., 1995; Puente et al., 2017).

The LPS showed acceptable accuracy for measures of speed and mean acceleration and deceleration for intermittent activities (Stevens et al., 2014). The WIMU PRO® system showed better accuracy (bias: 0.57–5.85%), test–retest reliability (%TEM: 1.19), and inter-unit reliability (bias: 0.18) in determining distance covered compared to GPS technology (bias: 0.69–6.05%; %TEM: 1.47; bias: 0.25) overall when both devices were worn by the same athlete (Bastida-Castillo et al., 2018). More recently, the WIMU PRO® system showed a mean absolute error of 5.2 ± 3.1 cm for the x-position and 5.8 ± 2.3 cm for the y-position. This represents percentage of differences of 0.97 ± 1% for the x-coordinate and 0.94 ± 1.14% for the y-coordinate (Bastida-Castillo et al., 2019). The inter-unit reliability showed a large ICC for the x-coordinate (0.65) and a very large ICC for the y-coordinate (0.88), and a good%TEM (2%) was reported for the error agreement between the two devices assessed.

To compare different playing levels, the database was divided into (a) top teams, defined as the two teams that reached the final of the tournament, and the (b) remaining six teams.

Statistical Analysis

Statistical analyses were performed using JASP (Amsterdam, Netherland) software version 0.10. Data are presented as mean and 95% credible intervals. In order to analyze the possible effects of the fixed factors [time epoch (30, 60, 180, and 300 s), playing positions (center, guard, and forward) and levels (two best classified teams and the remaining six teams), playing period (first quarter, second quarter, third quarter, and fourth quarter), and match scoring (winning, losing, and drawing) at the moment of the most demanding scenarios] on the dependent variables previously described [high-intensity accelerations (number and distance covered) and decelerations (number and distance covered), relative distance covered, and relative distance covered in established speed zones], separate ANOVAs were conducted using a Bayesian statistical approach. Individual "player code" was treated as a random factor for all analysis.

The Bayesian methodology [based on the quantification of the relative degree of evidence for supporting two rival hypotheses, null hypothesis (H_0) vs. alternative hypothesis (H_1), by means of the Bayesian factor (BF_{10}) (Linke et al., 2018; Doncaster et al., 2019)] has been recently suggested as an alternative to the traditional frequentist statistics (based on confidence intervals and p values) for hypothesis testing due to (among others) the following benefits: the BF_{10} quantifies evidence that the data provide for H_0 vs. H_1, the BF_{10} can quantify evidence in favor of H_0, and the BF_{10} is not "violently biased" against H_0 (Ly et al., 2016; Wagenmakers et al., 2018).

The BF_{10} was interpreted using the evidence categories suggested by Lee and Wagenmakers (2013): $< \frac{1}{100}$ = extreme evidence for H_0, from $\frac{1}{100}$ to $< \frac{1}{30}$ = very strong evidence for H_0, from $\frac{1}{30}$ to $< \frac{1}{10}$ = strong evidence for H_0, from $\frac{1}{10}$ to $< \frac{1}{3}$ = moderate evidence for H_0, from $\frac{1}{3}$ to <1 anecdotal evidence for H_0, from 1 to 3 = anecdotal evidence for H_1, from >3 to 10 = moderate evidence for H_1, from >10 to 30 = strong evidence for H_1, from >30 to 100 = very strong evidence for H_1, and >100 extreme evidence for H_1.

In order to provide a high probability of obtaining compelling evidence, only those ANOVAs that showed at least strong (10 times higher) evidence for supporting H_1 ($BF_{10} > 10$) and a percent error <0.001 (which indicates great stability of the numerical algorithm that was used to obtain the result) were considered robust enough to identify true differences between models (null model vs. factor-specific model), and posterior *post hoc* analyses were then carried out. Paired comparisons were based on either the Bayesian independent samples t-test (for normally distributed variables) with a Cauchy prior (0, $r = \frac{1}{\sqrt{2}}$) or the Bayesian Mann–Whitney U test (for non-normally distributed variables). The distribution of raw data sets was checked through the Shapiro–Wilk Expanded test. The posterior odds were corrected for multiple testing by fixing to 0.5 the prior probability that the null hypothesis holds across all comparisons (Westfall et al., 1997). Again, a BF > 10 was needed to consider a difference in any paired comparison as significant.

The median and the 95% central credible interval of the posterior distribution of the standardized effect size (δ) (i.e., the population version of Cohen's *d*) were also calculated for each of the paired comparisons carried out. Magnitudes of the posterior distribution of the standardized effect size were classified as: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0), and very large (>2.0–4.0) (Batterham and Hopkins, 2006).

From a training prescription standpoint, small changes in the physical demand measures selected in the current study are unlikely to influence a coach's prescription of training drills. Therefore, this study established the following requirements that needed to be fulfilled in order to infer that a difference noted between paired comparisons across the different fixed factors in the physical demand measures recorded was substantial or relevant from the perspective of ensuring a proper design of training tasks: (a) $BF_{10} > 10$ (at least strong evidence for supporting H_1) and (b) $\delta > 0.6$ (at least moderate).

RESULTS

A total of 29,867 observations (i.e., peak scores) from 10 physical demand measures, 13 matches, 94 players, and four different time epochs were collected.

Table 1 displays the descriptive statistics of the dependent variables recorded for each time epoch. For the Bayesian ANOVA conducted with the time epoch as a fixed factor, the results showed extreme evidence (BF > 100 and percentage error <0.001) that supports the existence of a main effect for time epoch for all movement demand variables (with the exception of the relative *distance covered at speed zone 4* and relative *distance covered at speed zone 5* variables) (**Table 1**). The subsequent *post hoc* analysis revealed substantial differences (BF > 10 and $\delta > 0.6$) in values for each dependent variable across all time epochs [with the exception of the *distance covered at speed zone 3 (running)*].

In **Tables 2** and **3** are presented the means and 95% credible intervals of the dependent variables in the four selected time epochs and separately for each player specific position and playing level, respectively. Likewise, in these tables are also shown their respective main ANOVA results. When playing position was included as a fixed factor in the Bayesian ANOVA, there was at least moderate evidence that supported the presence of significant positional differences in the following variables: accelerations (distance covered and number), decelerations (distance covered and number), relative distance at speed zone 1 (stationary/walking), and relative distance at speed zone 2 (jogging). Specifically, the *post hoc* analysis showed that centers had lower scores in the aforementioned variables than forward and guards. However, the magnitudes of these differences were only substantial (BF > 10 and $\delta > 0.6$) for the paired comparison between centers and guards in the acceleration [distance (from -9.7 to -23.3 m) and number (from -2.4 to -4.8)], deceleration [distance (from -14.6 to -26.5 m) and number (from -3.9 to -6.2)], and relative distance at speed zone 1 (from -33.1 to -65.7 m) variables registered using a 300 s time epoch. Likewise, substantial differences between centers and guards were also found in the numbers of high-intensity decelerations for the 60 s (from -1.2 to -2.1) and 180 s (from -2.8 to -4.4) time epochs and in the relative distance at speed zone 1 for the 180 s time epoch (from -18.3 to -40.5 m). For its part, the Bayesian analysis did not demonstrate the existence of significant differences in any dependent variable in relation to the playing level (BF < 10).

TABLE 1 | The most demanding scenario of basketball match play for four different time epochs (mean and 95% credible intervals).

Variable	**Time epochs**							
	30 s		**60 s**		**180 s**		**300 s**	
Accelerations*								
Distance covered (m)	26.5	(25.9–26.9)$^{\mathbf{b,c,d}}$	35.9	(35.2–36.6)$^{\mathbf{a,c,d}}$	65.7	(64.3–67)$^{\mathbf{a,b,d}}$	87.7	85.8–89.5$^{\mathbf{a,b,c}}$
Number	4.9	(4.8–5)$^{\mathbf{b,c,d}}$	6.9	(6.8–7)$^{\mathbf{a,c,d}}$	13.3	(13.1–13.6)$^{\mathbf{a,b,d}}$	18	(17.7–18.3)$^{\mathbf{a,b,c}}$
Decelerations*								
Distance covered (m)	23.3	(22.8–23.8)$^{\mathbf{b,c,d}}$	32.7	(31.8–33.5)$^{\mathbf{a,c,d}}$	53.7	(52.5–54.9)$^{\mathbf{a,b,d}}$	71.2	(69.5–72.8)$^{\mathbf{a,b,c}}$
Number	4.6	(4.5–4.7)$^{\mathbf{b,c,d}}$	6.4	(6.3–6.5)$^{\mathbf{a,c,d}}$	11.8	(11.6–12.1)$^{\mathbf{a,b,d}}$	16	(15.7–16.3)$^{\mathbf{a,b,c}}$
Relative distance covered*	71.8	(71–75.5)$^{\mathbf{b,c,d}}$	120.4	(119.2–121.6)$^{\mathbf{a,c,d}}$	282.6	(279.6–285.6)$^{\mathbf{a,b,d}}$	428.6	(422.4–434.8)$^{\mathbf{a,b,c}}$
Relative distance covered at different speed zones (m)								
Zone 1 (stationary/walking)	62.1	(61.3–62.9)$^{\mathbf{b,c,d}}$	94.9	(93.5–96.2)$^{\mathbf{a,c,d}}$	193.8	(190.7–196.8)$^{\mathbf{a,b,d}}$	273.6	(269.5–278.1)$^{\mathbf{a,b,c}}$
Zone 2 (jogging)	38.2	(37.4–38.9)$^{\mathbf{b,c,d}}$	48.7	(47.5–49.7)$^{\mathbf{a,c,d}}$	88.9	(86.9–90.9)$^{\mathbf{a,b,d}}$	119.8	(116.9–122.6)$^{\mathbf{a,b,c}}$
Zone 3 (running)	13.6	(13.1–14)$^{b,\mathbf{c,d}}$	15	(14.5–15.4)$^{a,\mathbf{c,d}}$	20.1	(19.4–20.9)$^{\mathbf{a,b},d}$	24.1	(23.1–25.1)$^{\mathbf{a,b},c}$
Zone 4 (high-intensity running)	8.2	(7.8–8.5)	8.4	(8–8.8)	9.5	(9–9.9)	10.3	(9.7–10.8)
Zone 5 (sprinting)	5.7	(5.2–6.3)	5.8	(5.2–6.3)	6.1	(5.5–6.7)	6.2	(5.6–6.9)

**The Bayesian ANOVA reported that there was at least a strong evidence (Bayes factor [BF_{10}] > 10 and percent error <0.001) to support the alternative hypothesis (H_1). Post hoc analysis: super-indices indicate that there was at least a strong evidence to support the presence of differences ($BF_{10} > 10$) against ^{a}30 s time epoch, ^{b}60 s time epoch, ^{c}180 s time epoch and ^{d}300 s time epoch. In bold are emphasized those sub-indices whose magnitude of the differences observed were at least moderate ($\delta > 0.6$). m: meters; s: seconds; km: kilometer; h: hour.*

Supplementary Appendices 1 and **2** show the values of the dependent variables in the four selected time epochs and separately for each playing period and match scoring at the moment of the most demanding scenarios. Despite the fact that the Bayesian analysis reported (with at least a strong degree of evidence) that in the first quarter, the scores of the high-intensity accelerations (distance covered and number) and decelerations (distance covered and number) and relative distance covered at speed zone 1 measured for the 300 s time epoch were higher than their counterparts showed in the last quarter (and in certain occasions, they were also lower than in the third quarter), the magnitude of these differences ($\delta < 0.6$) was not large enough to overcome the cutoff score established to fulfill the second requirement needed to consider any change as substantial. Similarly, there was not enough evidence to support any relevant effect elicited by the factor of match scoring at the moment of the most demanding scenarios on the physical demand measures analyzed (**Supplementary Appendix 2**).

DISCUSSION

The current study provides novel results that may help coaches and strength and conditioning specialists to better understand the most demanding scenarios of basketball games and, thus, improve evidence-based approaches when designing effective training and rehabilitation interventions. In particular, this study has described the most demanding scenarios of competitive basketball match play from under-18 teams through 10 physical demand measures and using four different rolling average time epochs: 30, 60, 180, and 300 s. Thus, and for example, the results showed that for the 60 s time epoch, the players performed 6.9 and 6.4 high-intensity accelerations and decelerations for a total covered distance of 120.4 m. Therefore, coaches and sports science specialists, when designing training drills with a duration of 60 s, should monitor that players achieve these just-mentioned peak physical demands in order to ensure proper preparation for what they will face during competitive match play. It should be also highlighted that as there were substantial differences (BF > 10 and $\delta > 0.6$) in values for most of the dependent variables across all time epochs, coaches and strength and conditioning specialists are advised to align the epoch length to the duration of the specific training drill that is being monitored or prescribed. For example, the number of high-intensity accelerations from a 60 s time epoch should not be extrapolated and utilized to assess and/or prescribe training drills that are longer (e.g., 90 s) or shorter (e.g., 45 s) in duration.

This activity profile described in the current study seems much more demanding than those found in previous studies using average measures instead of rolling average time epochs (Abdelkrim et al., 2007; Vázquez-Guerrero et al., 2019). In particular, Vázquez-Guerrero et al. (2019) showed that basketball players averaged 1.8 and 1.5 high-intensity accelerations and decelerations and covered a relative distance of 72.6 m min^{-1}. A similar trend has been observed in previous studies conducted in other sports, such as associated football (Abbott et al., 2018; Delaney et al., 2018; Martín-García et al., 2018; Casamichana et al., 2019), rugby (Delaney et al., 2016; Cunningham et al., 2018), Gaelic football (Malone et al., 2017), and Australian football (Delaney et al., 2017).

Another important finding reports that during the most demanding scenarios, the physical demands of match play are position-dependent (with the exception of the relative distances covered at speed zones 3, 4, and 5), the magnitude of these differences being larger for the longer time epochs. Consequently, it may be suggested that reducing the time epoch homogenizes the physical demands imposed on players. Thus, the centers performed a lower amount of high-intensity

TABLE 2 | The most demanding scenario of basketball match play for three different playing positions (mean and 95% credible intervals).

Time epoch (s)	Playing positions					
	Center		Forward		Guard	
Accelerations [distance covered (m)]*						
30	23.5	(22.3–24.7)[b,c]	26.8	(26–27.6)[a]	27.1	(26.4–27.8)[a]
60	32.1	(30.4–33.8)[b,c]	36.1	(35.1–37.2)[a]	37	(35.9–38.1)[a]
180	57.9	(54.3–61.4)[b,c]	65.3	(63.2–67.4)[a]	68.5	(66.5–70.5)[a]
300	75.8	(70.8–80.8)[b,c]	86.7	(83.9–89.5)[a]	92.3	(89.6–94.9)[a]
Accelerations (number)*						
30	4.4	(4.2–4.6)[b,c]	4.8	(4.7–4.9)[a]	5.1	(5–5.3)[a]
60	6.2	(5.9–6.5)[c]	6.7	(6.6–6.9)[c]	7.3	(7.2–7.5)[a,b]
180	11.7	(11.1–12.4)[b,c]	12.9	(12.6–13.3)[a,c]	14.2	(13.9–14.6)[a,b]
300	15.7	(14.8–16.6)[b,c]	17.4	(16.9–17.9)[a,c]	19.3	(18.8–19.8)[a,b]
Decelerations [distance covered (m)]*						
30	20.4	(19.3–21.6)[b,c]	23.2	(22.5–23.9)[a]	24.4	(23.7–25.1)[a]
60	29.1	(26.8–31.3)[c]	32.3	(31–33.6)	34.3	(33.1–35.6)[a]
180	44.1	(41.2–47)[b,c]	52.8	(50.9–54.7)[a,c]	57.6	(55.9–59.4)[a,b]
300	56.4	(52.4–60.4)[b,c]	69.8	(67.3–72.4)[a,c]	76.9	(74.7–79.2)[a,b]
Decelerations (number)*						
30	3.9	(3.7–4.2)[b,c]	4.5	(4.4–4.6)[a,c]	4.9	(4.8–5.1)[a,b]
60	5.3	(5.1–5.6)[b,c]	6.1	(5.9–6.3)[a,c]	6.9	(6.8–7.2)[a,b]
180	9.4	(8.9–9.9)[b,c]	11.4	(11.1–11.7)[a,c]	13.1	(12.7–13.4)[a,b]
300	12.7	(11.9–13.5)[b,c]	15.2	(14.8–15.7)[a,c]	17.7	(17.2–18.2)[a,b]
Relative distance covered (m)*						
30	67.2	(65.4–69.1)[b,c]	71.4	(70.2–72.6)[a]	73.5	(72.3–74.6)[a]
60	113	(110.4–115.7)[b,c]	120	(117.9–121.6)[a]	123.4	(121.7–125.3)[a]
180	261.5	(253.6–269.4)[b,c]	282.6	(278–287.2)[a]	289.5	(285.1–293.9)[a]
300	394.7	(375.6–413.7)[b,c]	429	(419.2–438.8)[a]	438.9	(430.7–447.2)[a]
Relative distance covered at the speed zone 1 (stationary / walking) (m)*						
30	56.1	(54.2–58.1)[b,c]	62.4	(61.2–63.6)[a]	63.9	(62.6–65.2)[a]
60	84.9	(81.7–88)[b,c]	94.9	(92.9–96.9)[a]	98.2	(96.1–100.2)[a]
180	171.9	(164.5–179.4)[b,c]	193.3	(188.5–197.9)[a]	201.3	(196.9–205.8)[a]
300	237.2	(226.2–248.2)[b,c]	272.2	(265.2–279.1)[a]	286.6	(280.2–293.1)[a]
Relative distance covered at the speed zone 2 (jogging) (m)*						
30	34.3	(32.4–36.2)[b,c]	38.9	(37.7–40.1)[a]	38.8	(37.6–39.9)[a]
60	43.1	(40.4–45.7)[b,c]	50.4	(48.7–52)[a]	48.8	(47.1–50.6)[a]
180	77.9	(73.3–82.7)[b,c]	90.3	(87–93.6)[a]	91.1	(88–94.2)[a]
300	103.7	(96.9–110.4)[b,c]	121.1	(116.5–125.6)[a]	123.7	(119.6–127.8)[a]
Relative distance covered at the speed zone 3 (running) (m)						
30	12.7	(11.6–13.7)	13.5	(12.8–14.1)	13.9	(13.3–14.5)
60	13.8	(12.6 – 15)	14.9	(14.1–15.7)	15.4	(14.7–16.1)
180	17.5	(15.8–19.3)	20.2	(18.9–21.4)	20.8	(19.7–21.9)
300	21.1	(18.6–23.5)	23.9	(22.3–25.5)	25.1	(23.7–26.5)
Relative distance covered at the speed zone 4 (high-intensity running) (m)						
30	7.6	(6.6–8.6)	8.2	(7.7–8.8)	8.3	(7.8–8.8)
60	7.7	(6.7–8.8)	8.5	(7.9–9.1)	8.5	(7.9–9.1)
180	8.3	(7.1–9.6)	9.6	(8.9–10.4)	9.5	(8.8–10.3)
300	9.2	(7.6–10.8)	10.3	(9.4–11.2)	10.5	(9.6–11.3)
Relative distance covered at the speed zone 5 (sprinting) (m)						
30	6.1	(3–9.3)	5.5	(4.9–6.2)	5.7	(4.9–6.4)
60	6.2	(3–9.3)	5.5	(4.9–6.2)	5.9	(5–6.7)
180	6.6	(3.3–9.9)	5.9	(5.2–6.5)	6.2	(5.2–7.2)
300	6.9	(3.7–10.3)	5.9	(5.2–6.6)	6.4	(5.4–7.4)

**The Bayesian ANOVA reported that there was at least a strong evidence [Bayes factor (BF_{10}) > 10] to support the alternative hypothesis (H_1) and percent error <0.001. Post hoc analysis: super-indices indicate that there was at least a strong evidence to support the presence of differences (BF_{10} > 10) against [a]center, [b]forward, and [c]guard. In bold are emphasized those sub-indices whose magnitude of the differences observed were at least moderate (δ > 0.6). m: meters; s: seconds; km: kilometer; h: hour.*

accelerations and decelerations and covered less distance than the forward, and much less than the guards. However, only the differences found between the centers and the guards for the high-intensity accelerations (number and distance covered) and decelerations (number) and relative distance covered at speed zone 1 measured at the 180 and 300 s time epochs may be considered relevant from a training prescription standpoint (BF > 10 and δ > 0.6). These results may partly be explained by the inherent tactical and technical requirements of the playing positions, players' individual physical demands, and the team play model (Abdelkrim et al., 2007). In fact, guards performed the highest number of high-intensity accelerations and decelerations presumably because these positions require a wide diversity of tactical movements such as hand-off, picks, and screen actions. Conversely, the lower amount of high-intensity accelerations and decelerations in centers could reflect the specificity of positional roles' actions, where they are required to occupy smaller spaces located nearer the basket (Sampaio et al., 2006). Similar playing position–related differences in physical demands of competition in basketball were found in previous studies using average scores (Ferioli et al., 2018; Stojanović et al., 2018; Svilar et al., 2018). Therefore, and unlike short-duration tasks, when coaches and sports science specialists want to design conditioning drills with a duration of 180 and 300 s and that replicate match physical demands, the positional differences should be taken into consideration so that the guards are subjected to higher physical demands (in terms of accelerations and decelerations and distance covered) than the forwards (e.g., two or three accelerations and decelerations more) but mainly compared to the centers (e.g., at least five accelerations and decelerations more). The activities that most likely can achieve this effect seem to be the small-sided game situations, because it's possible in these tasks to preserve match informational characteristics and have the players attending to the overall needs imposed by their roles. In these situations, it should be noted that coaches might benefit from adjusting interventions to instruct the players according to the time epochs. For example, if targeting a small-sided game situation with the most demanding scenario at a time epoch of 180 s, any game stoppage should be minimized or even completely avoided.

Regarding the playing level (i.e., tournament outcome), the results of this study did not show substantial differences between the two teams that played the final and the rest of the teams in any physical demand measure recorded during the most demanding scenarios of match play. This circumstance suggests that increased higher-intensity activity is not a decisive factor for winning. At this level of play, all teams reaching this stage of the tournament have already shown quality of play; therefore, it might be likely that a team unable to keep intense game paces would not reach the tournament qualification.

Similarly, this study did not find substantial differences in the physical demand measures selected according to the playing period (match quarter) at the moments of the most demanding scenarios. It might suggest that players may not have experienced enough fatigue that impaired physical performance during the game, as the rules allow for unlimited substitutions. Contrarily, previous research showed a significant reduction in

TABLE 3 | The most demanding scenario of basketball match play for two different playing levels (mean and 95% credible intervals).

Time epoch (s)	Playing level			
	Two best teams		Remaining teams	
Accelerations [distance covered (m)]				
30	26.4	(25.5–27.3)	26.5	(25.9–27.1)
60	35.9	(34.7–37.1)	35.9	(35.1–36.8)
180	65.6	(63.2–68.1)	65.7	(64–67.3)
300	89.8	(86.5–93.1)	86.8	(84.5–89)
Accelerations (number)				
30	5	(4.9–5.2)	4.9	(4.8–4.9)
60	7.2	(6.9–7.4)	6.8	(6.7–6.9)
180	13.9	(13.5–14.4)	13.1	(12.8–13.3)
300	18.9	(18.2–19.5)	17.7	(17.3–18.1)
Decelerations [distance covered (m)]				
30	22.8	(21.9–23.6)	23.6	(23–24.2)
60	33.8	(32.2–35.5)	32.2	(31.3–33.2)
180	52.6	(50.6–54.6)	54.2	(52.6–55.7)
300	71.2	(68.4–74.1)	71.1	(69.1–73.2)
Decelerations (number)				
30	4.7	(4.5–4.8)	4.6	(4.5–4.7)
60	6.5	(6.2–6.7)	6.4	(6.2–6.5)
180	12.2	(11.8–12.6)	11.7	(11.4–11.9)
300	16.6	(15.9–17.2)	15.7	(15.3–16.1)
Relative distance covered (m)				
30	72.4	(71.1–73.7)	71.5	(70.6–72.5)
60	122.2	(120.1–124.2)	119.7	(118.2–121.1)
180	285.6	(280.2–290.9)	281.4	(277.8–285.1)
300	426.2	(418.1–434.2)	429.7	(421.6–437.8)
Relative distance covered at the speed zone 1 (stationary/walking) (m)				
30	61.9	(60.4–63.6)	62.2	(61.3–63.2)
60	95.8	(93.4–98.2)	94.5	(92.9–96.1)
180	195.6	(190.1–201.1)	193	(189.4–196.7)
300	276.4	(268.6–284.2)	272.4	(266.9–277.9)
Relative distance covered at the speed zone 2 (jogging) (m)				
30	37.6	(36.2–38.9)	38.4	(37.5–39.4)
60	45.1	(42.9–47.4)	50.1	(48.8–51.4)
180	89.1	(85.5–92.8)	88.8	(86.3–91.3)
300	120.8	(116.1–125.5)	119.4	(115.9–122.9)
Relative distance covered at the speed zone 3 (running) (m)				
30	13.97	(13.3–14.7)	13.4	(12.9–13.9)
60	15.44	(14.6–16.3)	14.7	(14.2–15.3)
180	21.17	(19.8–22.5)	19.7	(18.7–20.6)
300	25.91	(24.1–27.7)	23.3	(22.1–24.4)
Relative distance covered at the speed zone 4 (high-intensity running) (m)				
30	8.22	(7.5–8.9)	8.2	(7.8–8.6)
60	8.42	(7.7–9.2)	8.4	(7.9–8.9)
180	9.54	(8.6–10.5)	9.4	(8.9–10)
300	10.86	(9.7–11.9)	10	(9.3–10.7)
Relative distance covered at the speed zone 5 (sprinting) (m)				
30	6.66	(5.5–7.8)	5.2	(4.8–5.7)
60	6.76	(5.6–7.9)	5.3	(4.8–5.8)
180	7.28	(5.9–8.7)	5.5	(4.9–6.1)
300	7.55	(6.1–9)	5.6	(5–6.3)

averaged relative distance and high-intensity accelerations and decelerations especially between the first and last quarters for players in all playing positions (Abdelkrim et al., 2007, 2010a; Vázquez-Guerrero et al., 2019; García et al., 2020). These contradictory results could be attributed to a methodological issue. In this sense, it has been reported that the fourth quarter of basketball match play [similar to the second half of football match play (Linke et al., 2018)] usually presents a longer total playing time [the sum of ball-in-play time (also called effective play time) and time dedicated to all game stoppages] than the first quarter (approximately 10 min more), mainly due to the higher number of substitutions, fouls, time-outs, and other actions that require interrupting the game (Scanlan et al., 2019). These game interruptions may have caused the just-mentioned reductions in averaged relative distance and high-intensity accelerations and decelerations between the first and fourth quarters observed in previous studies reporting the average physical demands of basketball match play. When a rolling average time epoch approach is used to describe the peak physical demands of play in intermittent team sports competitions (including basketball), game interruptions is not a factor that can bias the results.

Finally, when comparing the most demanding scenarios for the physical demands and the scoring for each quarter, no strong statistical evidence appeared except for the distance covered at >12 km/h at the 300 s time epoch. It might suggest that physical demands in basketball are not dependent on the score during periods less than 5 min. Moreover, it could also indicate that both teams adjust the physical demands according to the opponent's team play, not depending on the score.

Further expansions of this study can be done by including individual information about the players, such as physical fitness measures that help to understand the players' maximal possibilities. The analysis of this study was done under a single tournament with congested fixtures; thus, the findings shown may not be extrapolated to describe the most demanding scenarios in preseason, season, and playoff moments. For technical reasons, the most demanding scenarios were calculated for each player without considering the rest of his teammates and opponents at the same moment, and consequently, we were not able to analyze the effect of having (or not) ball possession (i.e., offense vs. defense match situation) and temporal changes in the team's and opposition's tactics and playing system on the most demanding scenarios of play in basketball competition. Future studies are warranted to address these issues.

CONCLUSION

The current study provided results from a high-level cohort of young basketballers, describing the most demanding scenarios of match play using time epochs of 30, 60, 180, and 300 s. The main practical application for coaches and strength and conditioning professionals is that most demanding scenarios can be used as an upper limit threshold in the training monitoring process. In fact, preparation to play high-level basketball requires the ability to perceive and act over the environment at extremely high game paces. Likewise, having these upper limits well defined is also a step forward in improving evidence-based approaches in the process of returning to play after injury.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Research Center in Sports Sciences, Health and Human Development (UID/DTP/04045/2013). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JV-G participated in the design of the study, contributed to data collection and interpretation of results. FA contributed to data reduction/analysis and interpretation of results. FG participated in the design of the study and contributed to data collection. JS contributed to data reduction/analysis. All authors contributed to the manuscript writing, read and approved the final version of the manuscript, and agreed with the order of presentation of the authors.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.00552/full#supplementary-material

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ESTUDIO 6

PEAK EXTERNAL INTENSITY DECREASES ACROSS QUARTERS DURING BASKETBALL GAMES

Fox, J. L., Salazar, H., Garcia, F., & Scanlan, A. T. (2021). Peak External Intensity Decreases across Quarters during Basketball Games. Montenegrin Journal of Sports Science and Medicine, 10 (1), 25-29. https://doi: 10.26773/mjssm.210304

ORIGINAL SCIENTIFIC PAPER

Peak External Intensity Decreases across Quarters during Basketball Games

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Abstract

The purpose of this study was to compare peak external intensities across game quarters in basketball. Eight semi-professional male players were monitored using accelerometers. For all quarters, peak intensities were determined via moving averages for PlayerLoad/minute (PL·min-1) using sample durations of 15 s, 30 s, 1 min, 2 min, 3 min, 4 min, and 5 min. Linear mixed models and effect sizes (ES) were used to compare peak intensities between quarters for each sample duration. Small decreases in peak PL·min-1 occurred between Quarters 1 and 4 for all sample durations (ES = 0.21-0.49). Small decreases in peak PL·min-1 were apparent between quarters 1 and 2 for 30-s, 1-min, and 3-min sample durations (ES = 0.24-0.33), and between quarters 3 and 4 for 2-5-min sample durations (ES = 0.20-0.24). Peak intensities decline across quarters with game progression in basketball, providing useful insight for practitioners to develop game-specific training and tactical strategies.

Keywords: *accelerometer, microsensor, training prescription, worst-case scenario*

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Introduction

In basketball, players are exposed to intense physical demands during games. Specifically, games involve frequent multi-directional movements (Taylor et al., 2017) along with substantial running demands (Stojanović et al., 2018). Given the physically demanding nature of basketball, optimal preparation leading into games is of critical importance to ensure that players can withstand the demands faced, consequently increasing the likelihood of successful performance (Fox et al., 2019).

Quantifying player demands across the entire game as well as during game quarters (Garcia et al., 2020) is essential to provide reference workloads and identify performance deficits across games, which in turn can be used to inform training prescription. In considering the demands encountered by players, data are typically expressed as either external demands or internal responses. Specifically, external demands represent the training or game stimuli imposed on players, while internal responses relate to the psychological and physiological reactions of players to the imposed demands (Impellizzeri et al., 2019). With respect to training prescription, the external demands represent the activity dosage directly prescribed and

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controlled by practitioners to bring about the desired responses and subsequent adaptations from players (Fox et al., 2019). In turn, it is essential to quantify the external demands experienced during games for training demands to prepare players for competitive scenarios effectively. In professional basketball players, external demands (total distance and player load) have been shown decrease (effect size (ES) = 1.27–1.31, large) between Quarter 1 and 4 (Garcia et al., 2020). In addition, external demands (high-intensity activity and PlayerLoad, respectively) have been shown to decrease across Quarter 3 and 4 (ES = 1.4–3.2, large-very large) (Scanlan et al., 2015), as well as overtime periods (ES = 1.46, large) (Scanlan et al., 2019), compared Quarters 1 and 2 during games in semi-professional players. Consequently, existing data suggest external demands decrease across games, likely as a function of changes in tactical approaches, and accumulated fatigue.

While understanding differences in external demands between game quarters is essential to prescribe training for basketball players more precisely, previous work has quantified total external load or average intensity across each quarter (Garcia et al., 2020; Scanlan et al., 2019). However, in better understanding the game demands experienced by players, the quantification of peak external intensities may provide further insights by determining the most demanding passages of game-play, also referred in the existing literature as "worst-case scenarios" (Cunningham et al., 2018). Specifically, understanding fluctuations in peak intensities between quarters may indicate player ability to sustain high-intensity activity across games for greater precision in prescribing training and managing fatigue-related outcomes. It is currently not clear whether trends reported in external demands across quarters are also apparent for metrics representing the most demanding passages of games. To date, no research has compared peak external intensities across game quarters in basketball, with only peak external intensities captured during entire games previously examined (Fox et al., 2020; Salazar & Castellano, 2019). Therefore, the purpose of this study was to compare peak external intensities encountered by players across game quarters in basketball.

Methods

Eight semi-professional, male basketball players (age: 23 ± 4 yr; stature: 191 ± 8 cm; body mass: 87 ± 16 kg; semi-professional playing experience: 5 ± 2 yr) volunteered to participate in the study. All players belonged to the same team competing in the Queensland Basketball League, a second-tier, state-level Australian basketball team. Other players from the same team received limited playing time across the season (<4 min per game) and therefore were not included in the study. Prior to study commencement, players were screened for injuries or health conditions that may have prevented safe participation. All players were informed of the purpose of the study and any potential risks or benefits of participation before providing voluntary written informed consent prior to participating. All procedures were approved by an institutional Human Research Ethics Committee.

Across the season, 18 games were scheduled, with 1-3 games held each week between Friday and Sunday. Each game consisted of 4 × 10-min quarters, with 2- and 15-min breaks between quarters and halves, respectively. Prior to study commencement, anthropometric data were collected on each player including stature using a portable stadiometer (Seca 213, Seca GMBH, Hamburg, Germany) and body mass using electronic scales (BWB-600, Tanita Corporation, Tokyo, Japan). For all games, players were fitted with microsensor units (OptimEye s5, Catapult Innovations, Melbourne, Australia) mounted at the upper torso, between the scapulae, in neoprene vests (Catapult Innovations, Melbourne, Australia). To reduce any potential between-device variability, players wore the same microsensor unit for each game across the season (Fox et al., 2019). External demands were measured via the 100-Hz accelerometer, housed within the microsensor unit, and exported as raw instantaneous PlayerLoad™ (PL) via proprietary software (OpenField version 8, Catapult Innovations, Melbourne, Australia). PL is the proprietary metric of the microsensor, which represents the square root of the change in acceleration across the transverse (x), coronal (y), and sagittal (z) planes (Montgomery et al., 2010). The reliability of PL has been previously supported in team sport athletes (Luteberget et al., 2017).

Raw PL data were then exported and processed in RStudio (version 3.5.3) using the "zoo" package. Moving averages were calculated for PL across consecutive samples spanning 15 s, 30 s, 1 min, 2 min, 3 min, 4 min, and 5 min. For each game, the highest intensity obtained by each player in each quarter for each sample duration was determined. Peak intensity was expressed as PL·min^{-1} by determining accumulated PL (sum of the raw PL across each duration), divided by 100, to represent the typical scaling factor applied (Montgomery et al., 2010). For each sample duration, PL was then reported relative to 1 min (e.g., the 15-s sample duration was multiplied by 4 to convert to PL·min^{-1}, and the 5 min sample duration was divided by 5 to convert to PL·min^{-1} (Fox et al., 2020)).

Peak PL·min^{-1} in each quarter for each sample duration is reported as mean ± standard deviation (SD). The normality of data distribution and sphericity were confirmed using the Shapiro-Wilk statistic and Levene's Test for equality of variances. For each sample duration, peak intensities in each game quarter were compared using linear mixed models with Bonferroni post hoc tests. The game quarter was entered as the fixed factor (4 levels), while the player (n = 8) was entered as the random term (Peugh, 2010). Effect sizes (Cohen's d) with 95% confidence intervals were computed for all pairwise comparisons to identify the magnitude of differences between game quarters. Magnitudes were interpreted as trivial: >0.20, small: 0.20–0.59, moderate: 0.60–1.19, large: 1.20–1.99, and very large: ≥2.00 (Hopkins, 2006). Where confidence intervals for effect sizes crossed ±0.2, the effect was interpreted as unclear (Hopkins et al., 2009). Linear mixed models and post-hoc tests were conducted using SPSS (Version 26, IBM Corporation, Armonk, USA) while effect sizes and confidence intervals were calculated using a customised Microsoft Excel spreadsheet (Version 15, Microsoft Corporation, Redmond, USA). Statistical significance was accepted where p <0.05.

Results

Peak PL·min^{-1} across game quarters for each sample duration are presented in Figure 1. Pairwise comparisons in peak PL·min^{-1} between quarters for each sample duration are presented in Table 1. For the 15-s, 1-min, 2-min, 4-min, and 5-min sample durations, differences in peak PL·min^{-1} between game quarters were non-significant, and effect sizes were trivial-small in magnitude (p >0.05). For the 30-s sample duration, differences in peak PL·min^{-1} between game quarters were

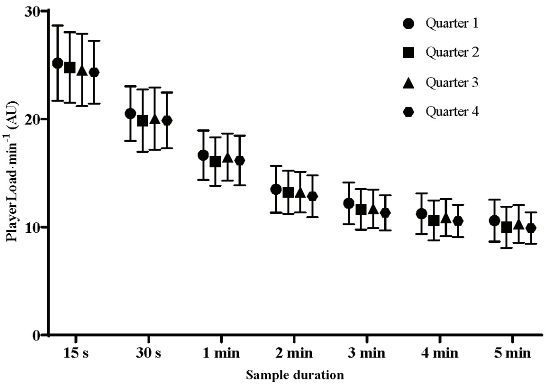

FIGURE 1. Peak intensity across basketball game quarters

non-significant, and effect sizes were unclear-small in magnitude (p >0.05). For the 3-min sample duration, there was a significant decline in peak PL·min^{-1} between Quarter 1 and Quarter 4 (p = 0.007, small), with all other differences in peak PL·min^{-1} between quarters being non-significant and trivial-small in magnitude (p >0.05).

Table 1. Pairwise comparisons in peak PlayerLoad per minute between game quarters for each sample duration in semi-professional, male basketball players.

Sample duration comparisons	*Effect size*	95% CI	*P*
15-s sample			
Quarter 1 vs Quarter 2	0.12	-0.12, 0.36	1.0
Quarter 1 vs Quarter 3	0.18	-0.06, 0.43	1.0
Quarter 1 vs Quarter 4	0.26*	0.01, 0.51	0.52
Quarter 2 vs Quarter 3	0.07	-0.18, 0.32	1.0
Quarter 2 vs Quarter 4	0.14	-0.11, 0.39	1.0
Quarter 3 vs Quarter 4	0.07	-0.19, 0.32	1.0
30-s sample			
Quarter 1 vs Quarter 2	0.24*	0.01, 0.48	0.56
Quarter 1 vs Quarter 3	0.17	-0.07, 0.42	1.0
Quarter 1 vs Quarter 4	0.25*	0.01, 0.49	0.73
Quarter 2 vs Quarter 3	-0.07	-0.31, 0.18	1.0
Quarter 2 vs Quarter 4	-0.01	-0.26, 0.24	1.0
Quarter 3 vs Quarter 4	0.06	-0.20, 0.31	1.0
1-min sample			
Quarter 1 vs Quarter 2	0.26*	0.02, 0.50	0.44
Quarter 1 vs Quarter 3	0.08	-0.16, 0.32	1.0
Quarter 1 vs Quarter 4	0.21*	-0.03, 0.46	0.90
Quarter 2 vs Quarter 3	-0.19	-0.43, 0.06	1.0
Quarter 2 vs Quarter 4	-0.04	-0.29, 0.21	1.0
Quarter 3 vs Quarter 4	0.14	-0.12, 0.39	1.0
2-min sample			
Quarter 1 vs Quarter 2	0.13	-0.11, 0.37	1.0
Quarter 1 vs Quarter 3	0.13	-0.11, 0.37	1.0
Quarter 1 vs Quarter 4	0.31*	0.07, 0.56	0.19
Quarter 2 vs Quarter 3	0.01	-0.25, 0.25	1.0
Quarter 2 vs Quarter 4	0.19	-0.06, 0.44	1.0
Quarter 3 vs Quarter 4	0.20*	-0.06, 0.45	1.0

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Sample duration comparisons	*Effect size*	95% CI	*P*
3-min sample			
Quarter 1 vs Quarter 2	0.30*	0.03, 0.54	0.18
Quarter 1 vs Quarter 3	0.27*	0.02, 0.51	0.37
Quarter 1 vs Quarter 4	0.49*	0.24, 0.74	**0.007**
Quarter 2 vs Quarter 3	-0.04	-0.28, 0.21	1.0
Quarter 2 vs Quarter 4	0.18	-0.07, 0.43	1.0
Quarter 3 vs Quarter 4	0.22*	-0.03, 0.48	1.0
4-min sample			
Quarter 1 vs Quarter 2	0.33*	0.09, 0.57	0.095
Quarter 1 vs Quarter 3	0.20*	-0.04, 0.44	1.0
Quarter 1 vs Quarter 4	0.40*	0.15, 0.64	0.057
Quarter 2 vs Quarter 3	-0.15	-0.39, 0.10	1.0
Quarter 2 vs Quarter 4	0.04	-0.21, 0.29	1.0
Quarter 3 vs Quarter 4	0.20*	-0.06, 0.45	1.0
5-min sample			
Quarter 1 vs Quarter 2	0.31*	0.07, 0.55	0.134
Quarter 1 vs Quarter 3	0.16	-0.09, 0.40	1.0
Quarter 1 vs Quarter 4	0.39*	0.14, 0.64	0.068
Quarter 2 vs Quarter 3	-0.04	-0.29, 0.20	1.0
Quarter 2 vs Quarter 4	0.05	-0.20, 0.30	1.0
Quarter 3 vs Quarter 4	0.24*	-0.01, 0.50	0.944

Note. CI = Confidence Interval, Bolded P value indicates significant (P <0.05) difference, * Indicates small effect size (0.20-0.59).

Discussion

The present study is the first to compare peak external intensities encountered across game quarters in semi-professional basketball. Our data revealed that for all sample durations assessed, there was a small decrease in peak intensity encountered between the first and fourth quarters. In addition, for all sample durations, except 15 s and 2 min, small declines in peak intensities were apparent between the first and second quarters. Our data also revealed small declines in peak intensity between the third and fourth quarters (2-, 3-, 4-, and 5-min sample durations) and first and third quarters (3- and 4-min sample durations).

In combination, our findings suggest that decreases in peak external intensities are evident across basketball games, with differences most prominent between the first and fourth quarters given this trend was revealed for all sample durations. Our findings also suggest that over longer sample durations (≥3 min), peak intensity decreases from the first to second and third to fourth quarters. Differences in peak PL·min-1 across games may be related to fatigue-related mechanisms with past research suggesting that factors such as glycogen depletion and muscle damage contribute to decreases in external demands across basketball games (Scanlan et al., 2015). These fatigue-related mechanisms may also explain why small differences in peak external intensities across all sample durations were obtained between the first and fourth quarters, whereas small differences in peak external intensity were obtained between the first and second quarters and between the third and fourth quarters only over longer sample durations. Given that exercise intensity is mediated by duration, player's maximal effort likely cannot be maintained at the same intensity for extended periods, which explains why small decreases in intensity were apparent within the same game half, over longer sample durations. In this regard, the break between halves allows for greater recovery opportunity (15 min) compared to between quarters (2 min), likely explaining the lack of any clear differences in peak PL·min^{-1} between the second and third quarters. In addition, longer sample durations likely include periods of inactivity or low-intensity activity (e.g., substitutions, time-outs, and stoppages in play for a change in possession of free-throw) which will also contribute to the lower intensities achieved. Lastly, the decline in peak intensities across games may also be related to tactical strategies, whereby game pace is reduced in later quarters to gain more ball control when in possession to increase the likelihood of successful game outcomes (Abdelkrim et al., 2007).

In interpreting the findings of the present study, some notable limitations should be considered. Data were collected on a semi-professional, male basketball team, so it cannot be assumed that the peak external intensities and differences in intensities observed between quarters are representative of female players (Scanlan et al., 2012) or players participating in other leagues or at other playing levels (Scanlan et al., 2011), suggesting that future work is needed to establish peak intensities encountered across various playing levels. In addition, only a single measure of intensity was assessed due to the frequent use of PL in basketball; however, when assessing game demands to optimize training prescription, other measures of intensity should also be explored.

Data from the present study suggest that peak external intensities decline across basketball games, with the most notable declines in intensity occurring between the first and fourth quarters. In addition, over longer sample durations (≥

3 min) peak external intensity decreased within each half (i.e., between Quarters 1 and 2 and between Quarters 3 and 4). Therefore, basketball practitioners should assess not only total external demands or average external intensity across game quarters, but should also consider the most intense periods of activity encountered across different sample durations to assist in guiding training prescription. In this regard, using reference peak external intensity values from the first quarter may be useful, given these data represent the highest external intensities reached across the entire game. Specifically, preparing players to be able to maintain external intensities encountered in the first quarter during later game periods may assist in managing player fatigue and promoting optimal preparation for games. In further optimizing training prescription, attention should also be given to data captured over sample durations ≥3 min as these longer durations appear to provide further insights regarding fluctuations in peak external demands encountered within each game half.

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COMUNICACIONES RELACIONADAS CON LA TESIS

EUROPEAN COLLEGE OF SPORTS SCIENCE ANUAL CONGRESS 2019 (ORAL PRESENTATION)

EXTERNAL LOAD BETWEEN PLAYING POSITIONS AND QUARTERS IN COMPETITIVE ELITE BASKETBALL

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INTRODUCTION

In order to prescribe training accordingly, it is essential to understand beforehand the specific demands of basketball during competition. To date, there is no research published using micro-technology in official basketball games due to multiple restrictions in the principal European leagues. The aim of this investigation is, therefore, to analyse possible differences between positions and quarters during elite level basketball competition.

METHODS

Thirteen professional basketball athletes competing with FC Barcelona in the second Spanish division (Leb gold) were monitored during 5 official matches with a local positioning system (WIMU PRO®, Realtrack Systems SL, Almería, Spain). To allow comparisons, all data was divided between minutes played per player. Two-way Anova and Bonferroni post-hoc were used to contrast differences between positions and quarters in six main variables: Distance (DIS), Player Load (PL), number of Accelerations (ACC) and Decelerations (DEC), Distance over 18 km/h (D18) and Jumps over 5G (JUM). In addition, Cohen's effect size (ES) and 90% confidence intervals (90% CI) were also calculated.

RESULTS

After analysing differences between quarters, it can be seen that only DIS was found significantly dissimilar between 1st and 4th period ($p = 0.04$; ES = 0.61; 90% CI = 0.25, 0.97). On the contrary, some meaningful changes ($p < 0.05$) were identified between positions. Firstly, guards covered greater DIS ($P < .001$; ES = 0.87; 90% CI = 0.59, 1.15) than centers; and accumulated greater PL ($p = 0.004$; ES = 0.61; 90% CI = 0.36, 0.86) than forwards. Secondly, forwards covered greater D18 ($p = 0.017$; ES = 0.55; 90% CI = 0.30, 0.80) than guards and larger DIS ($p = 0.01$; ES = 0.67; 90% CI = 0.36, 0.98) than centers. To end, centers had higher JUM than both guards ($p = 0.48$; ES = 0.39; 90% CI = 0.12, 0.67) and forwards ($p = 0.004$; ES = 0.61; 90% CI = 0.30, 0.91). Regarding ACC and DEC, it can be said that these variables did not show significant variations between any of the two factors studied.

DISCUSSION

This research shows almost no significant differences between values across quarters in the six variables studied. Nevertheless, DIS was found to exhibit a moderate increase in the last period of the game, where the majority of matches are decided in professional basketball. In regards of the differences between positions, some significant differences were detected. As an example, PL tends to be higher in guards compared with forwards and centers. Moreover, this investigation also found that the position that performs the highest number of jumps were the centers. A possible explanation for this is the fact that they are the tallest athletes in the team and normally play around the ring performing vertical actions such as rebounding and blocking shots, for instance. To sum up, enhanced understanding of the differences between quarters and, specially, positions will allow practitioners to prescribe training in a much more individualised manner.

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Letter of Acceptance

This is to certify that the following title has been accepted at the 24th Annual Congress of the European College of Sport Science between 3 - 6 July 2019 in Prague - Czech Republic:

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INTERNATIONAL SPORT FORUM ON STRENGTH, TRAINING AND NUTRITION ANNUAL CONGRESS 2019 (POSTER)

PHYSICAL DEMANDS DURING OFFICIAL COMPETITION IN ACADEMY (U12 to U18) AND SENIOR BASKETBALL

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INTRODUCTION

Physical game demands on senior players using inertial micro-sensors have recently been widely described (Svilar et al., 2018; Vázquez-Guerrero et al., 2018). However, under 18 (U18) is the only academy age-group that has been examined during basketball competition (Vázquez-Guerrero et al., 2019).

Understanding physical demands encountered during competition in academy and senior basketball could help strength and conditioning coaches and sport scientists to optimize training process, game performance and talent identification processes.

The aim of this research is, therefore, to compare the physical demands between five different age-groups (U12, U14, U16, U18 and seniors) during official basketball competition.

METHODOLOGY

SUBJECTS: 64 basketball athletes (Table 1) competing with FC Barcelona in five different teams were monitored during a range of 8 to 17 league games.

PROCEDURES: A valid and reliable local positioning system (WIMU PRO®, Realtrack Systems SL, Almería, Spain) was used (Bastida-Castillo et al., 2019). Inertial devices (81 x 45 x 16 mm, 70g) were fitted in a custom vest located on each player's upper back using an adjustable harness.

VARIABLES: Total distance covered (DIST), player load (PL), number of accelerations ≥ 2 m·s^{-2} (ACC) and decelerations ≤ 2 m·s^{-2} (DEC), distance > 18 km·h^{-1} (D18) and peak velocity (PV). Except PV (expressed in absolutes values), all variables were relativized with total minutes spent on court (only excluding breaks between periods).

STATISTICAL ANALYSES: ANOVA & Bonferroni post-hoc were used to contrast differences between age-groups. In addition, Cohen's effect size (ES) and 90% confidence intervals (90% CI) were also calculated.

	n	Age (y)	Height (cm)	Body mass (kg)	Wingspan (cm)
U12	11	11.2 ± 0.3	167.0 ± 8.0	56.9 ± 11.9	167.6 ± 8.2
U14	14	13.0 ± 0.4	175.3 ± 6.4	60.9 ± 8.9	179.1 ± 7.6
U16	16	15.0 ± 0.5	194.7 ± 7.8	80.1 ± 10.5	200.1 ± 7.6
U18	12	16.8 ± 0.6	198.5 ± 9.3	88.7 ± 13.7	202.8 ± 11.1
Senior	11	19.6 ± 1.5	199.4 ± 9.0	90.5 ± 17.1	201.2 ± 7.9

Table 1. Anthropometry results according to age

DISCUSSION

Total distance covered and player load presented a decreased tendency with age, probably due to 3 possible different factors:

1) Players with more experience tend to interpret the game better and optimize their decision-making.
2) Senior basketball usually have a slower game pace because of a greater complexity and a larger number of set plays.
3) Total time used to calculate relative values showed an increased tendency with age-groups due to an increased number of stops such as free-throws and fouls.

On the contrary, peak velocity and distance > 18 km·h^{-1} showed an increased tendency with age, probably affected by maturation status.

Finally, although accelerations and decelerations did not present numerous significant differences between age-groups, U12 team showed greater values than seniors. This results could demonstrate that the 2 m·s^{-2} threshold could be insufficient to categorize accelerations and decelerations as high-intensity efforts.

RESULTS

	PV (km·h^{-1})	DIST (m·min^{-1})	D18 (m·min^{-1})	ACC (n·min^{-1})	DEC (n·min^{-1})	PL (a.u.·min^{-1})
U12	19.2 ± 2.8	87.9 ± 6.4	2.2 ± 1.5	3.9 ± 1.2	3.6 ± 1.2	1.8 ± 0.3
U14	19.9 ± 1.3	80.4 ± 6.9	3.1 ± 1.6	3.5 ± 1.0	3.2 ± 1.1	1.5 ± 0.2
U16	20.6 ± 1.4	79.8 ± 5.6	3.3 ± 1.5	3.9 ± 1.1	3.5 ± 1.1	1.4 ± 0.2
U18	20.8 ± 1.5	82.5 ± 8.7	4.1 ± 1.4	3.8 ± 1.1	3.4 ± 1.1	1.3 ± 0.2
Senior	20.7 ± 1.5	72.4 ± 8.1	3.2 ± 1.2	3.5 ± 1.0	3.1 ± 1.0	1.3 ± 0.2

Table 2. Means (±SD) in selected physical demands for the five teams examined

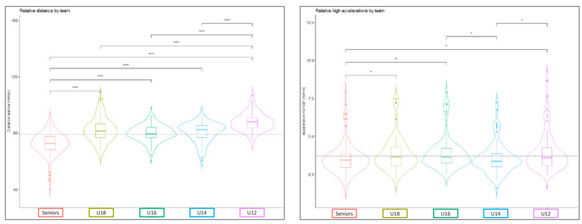

Figure 1. Tendency of the five age-groups analyzed in 1) total distance covered and 2) number of accelerations ≥ 2 m·s^{-2}
***** = p<0.0001, *** = p<0.001, ** = p<0.01, * = p<0.05*

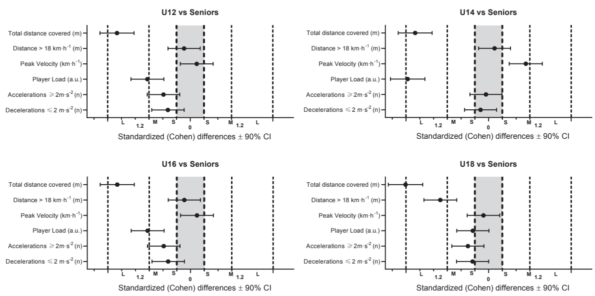

Figure 2. Standardized differences (Cohen's d) and the 90% confidence intervals between the four academy and senior basketball teams for the six physical demands variables selected

CONCLUSIONS

- Total distance covered & player load showed a decreased tendency with age, while peak velocity & distance >18 km·h^{-1} tended to increased with basketball categories.
- Number of accelerations and decelerations were the variables that presented less variability between age-groups.
- The use of fixed thresholds for high-speed running (>18 km·h^{-1}) and high-intensity accelerations (≥2 m·s^{-2}) and decelerations (≤-2 m·s^{-2}) could have impaired comparisons between players with different maturation status and physical capacities.
- In order to optimize game performance, future research should analyse player's physical demands during the most demanding scenarios of match-play, also referred as "worst-case scenarios".

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