UNIVERSITAT DE BARCELONA

Monitorización de la carga de entrenamiento y competición en baloncesto femenino: jóvenes y alto nivel

Francisco Javier Espasa Labrador

inefc
Institut Nacional d'Educació Física de Catalunya
Barcelona

Generalitat de Catalunya

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TESIS DOCTORAL

Francisco Javier Espasa Labrador

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Monitorización de la carga de entrenamiento y competición en baloncesto femenino: jóvenes y alto nivel

Francisco Javier Espasa Labrador

Dirigida por:

Azahara Fort-Vanmeerhaeghe, PhD

Marta Carrasco-Marginet, PhD

Tutorizada por:

Dr. Xavier Iglesias Reig, PhD

Programa de doctorado en Actividad Física, Educación Física y Deporte
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“Solo yo duermo conmigo,
solo yo me veo despertar
y solamente el suelo que piso me escucha al andar.”

Meiuqèr, Izal

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Certificado supervisión de tesis doctoral

Azahara Fort-Vanmeeerhaeghe. Blanquerna, Universidad Ramon Llull

Declaro que:

Que la presente tesis doctoral titulada **Monitorización de la carga de entrenamiento y competición en el baloncesto femenino: jóvenes y alto nivel** y presentada por **Francisco Javier Espasa Labrador** para obtener el grado de doctor, es un compendio de publicaciones y ha sido realizada bajo mi supervisión.

A todos los efectos, firmo el presente documento.

Azahara Fort-Vanmeerhaeghe
Directora de la tesis doctoral.

Barcelona, 23 de octubre de 2023.

Certificado supervisión de tesis doctoral

Marta Carrascto Marginet. INEFC Barcelona, Universidad de Barcelona

Declaro que:

Que la presente tesis doctoral titulada **Monitorización de la carga de entrenamiento y competición en el baloncesto femenino: jóvenes y alto nivel** y presentada por **Francisco Javier Espasa Labrador** para obtener el grado de doctor, es un compendio de publicaciones y ha sido realizada bajo mi supervisión.

A todos los efectos, firmo el presente documento.

Marta Carrasco Marginet
Directora de la tesis doctoral.

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Lista de publicaciones

Esta tesis doctoral se basa en las siguientes publicaciones, que se detallan a continuación y a las que se hace referencia en el texto con sus números romanos:

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Factor de impacto (2022): 3,9

III. **Espasa-Labrador, J**., Peña, J. Caparrós Pons, T., Cook, M., Fort-Vanmeerhaeghe, A. Relationship between internal and external load in elite female youth basketball players. *Apunts Sports Medicine*, *56*(211) https://doi.org/10.1016/j.apunsm.2021.100357.

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I. **Espasa-Labrador, J.**, Caparrós-Pons, Toni, Fort-Vanmeerhaeghe, A. (23-25 de septiembre de 2017). *Internal and external training loads by positions during basketball training in elite female young basketball players* [Comunicación poster]. Interdisciplinar 1st Physical Prevention and Rehabilitation. Granada, España.

II. **Espasa-Labrador, J.**, Caparrós-Pons, Toni, Fort-Vanmeerhaeghe, A. (5-6 de octubre de 2017). *Comparison between training load and preseason load in young elite female basketball players* [Comunicación poster]. Linking theory and practice. Complex System in Sports International Congress. Barcelona, España.

III. **Espasa-Labrador, J.** Calleja-González, J., Fort-Vanmeerhaeghe, A. (17-18 de junio 2022). *Control de la carga externa e interna en el baloncesto femenino: revisión sistemática* [Comunicación oral]. III Congreso Asepreb, Valencia, España.

Lista de tablas

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Glosario

+/-	Índice de diferencia de puntos logrados por el equipo durante un período
3x3	Baloncesto 3 contra 3
5x5	Baloncesto 5 contra 5
BLC	Concentración de lactato en sangre (siglas en inglés)
DALDA	Análisis diario de las exigencias vitales de los deportistas (siglas en inglés)
EL	Euroliga (1ª División de Baloncesto en Europa)
EVCTT	Escala de valoración de cargas técnico-tácticas
FC	Frecuencia cardíaca
$FC_{máx}$	Frecuencia cardíaca máxima
FC_{media}	Frecuencia cardíaca promedio
FIBA	*International Basketball Federation*
GNSS	Sistema de navegación global por satélite (siglas en inglés)
GPS	Sistema de posicionamiento global (siglas en inglés)
IMU	Unidad de movimiento inercial (siglas en inglés)
IZOF	Zona individual de funcionamiento óptimo (siglas en inglés)
LCA	Ligamento cruzado anterior
LF	Liga Femenina (1ª División del Baloncesto en España)
PL	*Player Load*
POMS	Perfil del estado de ánimo (siglas en inglés)
PS	Percepción subjetiva
Rest-Q	Cuestionario de descanso (siglas en inglés)
RPE	Percepción subjetiva del esfuerzo (siglas en inglés)
SHRZ	Sumatorio de las zonas de frecuencia cardíaca (siglas en inglés)
SIATE	Sistema integral para el análisis de las tareas de entrenamiento
sRPE	Percepción subjetiva del esfuerzo de la sesión (siglas en inglés)
TCC	Temperatura corporal central
$TRIMP_B$	Impulsos de entrenamiento de Banister (siglas en inglés)
UA	Unidades arbitrarias
VO_2	Consumo de oxígeno
WNBA	*Women's National Basketball Association* (1ª División del Baloncesto en Estados Unidos de America)

ÍNDICE

RESUMEN

Resumen

El baloncesto femenino, en sus modalidades de 5x5 y 3x3, es un deporte global con reglas específicas que requiere de acciones de alta intensidad, habilidades técnicas y conocimiento táctico en un entorno impredecible y de constante cambio. En la evaluación del rendimiento, se han desarrollado indicadores que van desde las acciones básicas del juego (puntos, rebotes, etc.) hasta estadísticas avanzadas (ritmo de juego, participación en el juego, etc.) y aspectos condicionales de las jugadoras (distancia total recorrida, número de acciones a alta intensidad, etc.). La monitorización de la carga de entrenamiento y competición, a través de tecnología, busca optimizar el proceso de entrenamiento y reducir el riesgo de lesiones. Este es el enfoque principal de la tesis doctoral, que tiene por objetivo general estudiar los métodos, métricas y valores reportados en la literatura científica al monitorizar la carga de entrenamiento y competición en el baloncesto femenino en los diferentes niveles competitivos.

Esta tesis doctoral se compone de cuatro estudios científicos que emplean diversas metodologías de investigación para alcanzar los objetivos previamente definidos. En primer lugar, se presentan dos revisiones sistemáticas con el fin de resumir y analizar la evidencia científica disponible sobre la demanda física (Publicación I) y la respuesta fisiológica (Publicación II) en el baloncesto femenino. Estos dos trabajos tienen como finalidad brindar una visión completa de referencia de las herramientas disponibles en la monitorización de la carga. En segundo lugar, se incluye el estudio científico de la monitorización de la carga de entrenamiento (Publicación III) realizado con jugadoras jóvenes de baloncesto de alto nivel (n = 13) y en el que se estudió la relación de los constructos de la carga, la demanda física y la respuesta fisiológica. Por último, se incluye un protocolo de investigación (Publicación IV) que consiste en la monitorización de la competición oficial en un equipo semiprofesional compuesto por jugadoras adultas (n = 12). Este estudio pretende analizar la relación que tienen las demandas físicas medidas a través de sensores inerciales con indicadores de rendimiento propios del juego reportados en la estadística. Esta relación podría facilitar la comprensión de los valores de carga en caso de no contar con este tipo de dispositivos.

Como resultado de las revisiones sistemáticas se incluyeron un total de 40 publicaciones científicas en el caso del estudio de la carga externa (Publicación I) y 44 en la monitorización de la carga interna (Publicación II). En primer lugar, las publicaciones que monitorizaron la carga externa estudiaron las demandas durante los entrenamientos (n = 11), los partidos (n = 20) o ambos eventos (n = 9). De entre todos los métodos reportados los sensores inerciales fueron utilizados de forma mayoritaria (n = 28/40), empleando frecuencias de muestreo de 100 Hz y colocando los dispositivos en la parte superior de la espalda. Sin embargo, se observó una amplia diversidad de métricas, destacándose la denominada como *Player Load* (PL), la cual se expresa en unidades arbitrarias (UA). Los diferentes estudios analizados rebelaron que las jugadoras de niveles competitivos más altos muestran demandas físicas mayores, un hallazgo que destaca la importancia de las capacidades condicionales de la jugadora como un pilar central en su rendimiento durante la competición. En el caso de la cuantificación de la carga durante el entrenamiento se observó un rango amplio de valores de carga (PL 5x5: 34.8 ± 8, PL 3x3: 47.6 ± 7.4 UA, distancia 5x5: 209.2 ± 35.8 m y distancia 3x3: 249.3 ± 2.8 m), lo que obstaculiza la extracción de conclusiones precisas. A pesar de esto, se destaca de este estudio que las tareas sin defensa parecen ser menos exigentes que las que emplearon oposición, independientemente de la población estudiada. Por otro lado, en el estudio de la carga interna (Publicación II), los métodos basados en la percepción subjetiva del esfuerzo (RPE) fueron los más utilizados (n = 28/44), seguidos de la monitorización de la frecuencia cardíaca (FC) (n = 27/44). En el caso del primero, la escala de 1-10 puntos fue la más común, mientras que la cuantificación de la FC se basó principalmente en reportar los valores de FC media, la FC mínima y máxima, el porcentaje de FC máxima y el tiempo que el miocardio de la jugadora pasaba en estas pulsaciones relativas. De este análisis se destaca que la FC media del entrenamiento presenta un rango más amplio de valores que la competición, ya que, durante el partido, el corazón responde con frecuencias altas debido a la intensidad del propio evento. Por último, se destaca que ninguna de estas publicaciones incluyó meta-análisis debido a la heterogeneidad de los datos, un aspecto que limitó las comparaciones entre los resultados obtenidos. A pesar de ello, se llevó a cabo un análisis de la calidad metodológica de los estudios, obteniendo puntuaciones consideradas como justas o buenas al emplear la guía de evaluación STROBE (*Strengthening the Reporting of Observational Studies in Epidemiology*).

En lo que respecta a los resultados del estudio de las cargas de entrenamiento (Publicación III) se observaron un rango de valores amplios en relación a la carga externa, evaluada a través de las aceleraciones totales (1767,0 ± 385,5), aceleraciones totales máximas (258,0 ± 82,2) y las aceleraciones (8,4 ± 1,2) y deceleraciones (8,4 ± 1,2) máximas por minuto. Por otro lado, la relación entre la demanda y la respuesta mostró niveles de correlación fuerte al vincular el total de aceleraciones con los impulsos de entrenamiento de Banister (0,8), un fenómeno explicable si tenemos en cuenta que ambas podrían ser consideradas métricas de volumen. En cuanto al resto de resultados se destaca la correlación del total de aceleraciones con los modelos de sumatorio de zonas de FC (SHRZ en inglés) y la percepción subjetiva de la jugadora en la sesión (sRPE), una relación grande (0,6 en ambos casos). Por último, en lo que respecta a las métricas de intensidad, el total de aceleraciones máximas presentan una asociación moderada (0,4) con los métodos que monitorizaron la carga interna (SHRZ y sRPE).

Los resultados de la presente tesis doctoral permiten una mejor comprensión del estado actual del uso de métodos, métricas y valores de referencia en la monitorización de la carga en el baloncesto femenino, un hecho que posibilita la mejora y optimización de la carga, tanto en el entrenamiento como en la competición. En el futuro, investigadores y clubes deportivos deberán trabajar por establecer consensos en el uso de estas referencias que se exponen, pero se deberán tener en cuenta las características propias de la mujer deportista, principalmente las fluctuaciones hormonales del ciclo menstrual, las cuales se ha visto cómo impactan en otros marcados fisiológicos y en la propia percepción subjetiva ante la carga.

Palabras clave: baloncesto femenino, carga, monitorización, rendimiento, demanda física

Resum

El bàsquet femení, en les seves modalitats de 5x5 i 3x3, és un esport global amb regles específiques que requereix d'accions d'alta intensitat, habilitats tècniques i coneixement tàctic en un entorn impredictible i de constant canvi. En l'avaluació del rendiment, s'han desenvolupat indicadors que van des de les accions bàsiques del joc (punts, rebots, etc.) fins a estadístiques avançades (ritme de joc, participació en el joc, etc.) i aspectes condicionals de les jugadores (distància total recorreguda, nombre d'accions a alta intensitat, etc.). El monitoratge de la càrrega d'entrenament i competició, a través de tecnologia, cerca optimitzar el procés d'entrenament i reduir el risc de lesions. Aquest és l'enfocament principal de la tesi doctoral, que té per objectiu general estudiar els mètodes, mètriques i valors reportats en la literatura científica en monitorar la càrrega d'entrenament i competició en el bàsquet femení en els diferents nivells competitius.

Aquesta tesi doctoral es compon de quatre estudis científics que empren diverses metodologies de recerca per a aconseguir els objectius prèviament definits. En primer lloc, es presenten dues revisions sistemàtiques amb la finalitat de resumir i analitzar l'evidència científica disponible sobre la demanda física (Publicació I) i la resposta fisiològica (Publicació II) en el bàsquet femení. Aquests dos treballs tenen com a finalitat brindar una visió completa de referència de les eines disponibles en el monitoratge de la càrrega. En segon lloc, s'inclou l'estudi científic del monitoratge de la càrrega d'entrenament (Publicació III) realitzat amb jugadores joves de bàsquet d'alt nivell (n = 13) i en el qual es va estudiar la relació dels constructes de la càrrega, la demanda física i la resposta fisiològica. Finalment, s'inclou un protocol de recerca (Publicació IV) que consisteix en el monitoratge de la competició oficial en un equip semiprofessional compost per jugadores adultes (n = 12). Aquest estudi pretén analitzar la relació que tenen les demandes físiques mesurades a través de sensors inercials amb indicadors de rendiment propis del joc reportats en l'estadística. Aquesta relació podria facilitar la comprensió dels valors de càrrega en cas de no comptar amb aquesta mena de dispositius.

Com a resultat de les revisions sistemàtiques es van incloure un total de 40 publicacions científiques en el cas de l'estudi de la càrrega externa (Publicació I) i 44 en el monitoratge de la càrrega interna (Publicació II). En primer lloc, les publicacions que van monitorar la càrrega externa van estudiar les demandes durant els entrenaments (n = 11), els partits (n = 20) o tots dos esdeveniments (n = 9). D'entre tots els mètodes reportats els sensors inercials van ser utilitzats de manera majoritària (n = 28/40), emprant freqüències de mostreig de 100 Hz i col·locant els dispositius en la part superior de l'esquena. No obstant això, es va observar una àmplia diversitat de mètriques, destacant-se la denominada com *Player Load* (PL), la qual s'expressa en unitats arbitràries (UA). Els diferents estudis analitzats van rebel·lar que les jugadores de nivells

competitius més alts mostren demandes físiques majors, una troballa que destaca la importància de les capacitats condicionals de la jugadora com un pilar central en el seu rendiment durant la competició. En el cas de la quantificació de la càrrega durant l'entrenament es va observar un rang ampli de valors de càrrega (PL 5x5: 34.8 ± 8, PL 3x3: 47.6 ± 7.4 UA, distància 5x5: 209.2 ± 35.8 m i distància 3x3: 249.3 ± 2.8 m), la qual cosa obstaculitza l'extracció de conclusions precises. Malgrat això, es destaca d'aquest estudi que les tasques sense defensa semblen ser menys exigents que les que van emprar oposició, independentment de la població estudiada. D'altra banda, en l'estudi de la càrrega interna (Publicació II), els mètodes basats en la percepció subjectiva de l'esforç (RPE) van ser els més utilitzats (n = 28/44), seguits del monitoratge de la freqüència cardíaca (FC) (n = 27/44). En el cas del primer, l'escala de 1-10 punts va ser la més comuna, mentre que la quantificació de la FC es va basar principalment a reportar els valors d'FC mitjana, l'FC mínima i màxima, el percentatge d'FC màxima i el temps que el miocardi de la jugadora passava en aquestes pulsacions relatives. D'aquesta anàlisi es destaca que l'FC mitjana de l'entrenament presenta un rang més ampli de valors que la competició, ja que, durant el partit, el cor respon amb freqüències altes a causa de la intensitat del propi esdeveniment. Finalment, es destaca que cap d'aquestes publicacions va incloure fiqui-anàlisi a causa de l'heterogeneïtat de les dades, un aspecte que va limitar les comparacions entre els resultats obtinguts. Malgrat això, es va dur a terme una anàlisi de la qualitat metodològica dels estudis, obtenint puntuacions considerades com a justes o bones en emprar la guia d'avaluació STROBE (*Stregthening the Reporting of Observational Studies in Epidemiology*).

Pel que fa als resultats de l'estudi de les càrregues d'entrenament (Publicació III) es van observar un rang de valors amplis en relació a la càrrega externa, avaluada a través de les acceleracions totals (1767,0 ± 385,5), acceleracions totals màximes (258,0 ± 82,2) i les acceleracions (8,4 ± 1,2) i desceleracions (8,4 ± 1,2) màximes per minut. D'altra banda, la relació entre la demanda i la resposta va mostrar nivells de correlació forta en vincular el total d'acceleracions amb els impulsos d'entrenament de Banister (0,8), un fenomen explicable si tenim en compte que ambdues podrien ser considerades mètriques de volum. Quant a la resta de resultats es destaca la correlació del total d'acceleracions amb els models de sumatori de zones d'FC (SHRZ) i la percepció subjectiva de la jugadora en la sessió (sRPE), una relació gran (0,6 en tots dos casos). Finalment, pel que fa a les mètriques d'intensitat, el total d'acceleracions màximes presenten una associació moderada (0,4) amb els mètodes que van monitorar la càrrega interna (SHRZ i sRPE).

Paraules clau: bàsquet femení, càrrega, monitoratge, rendiment, demanda física

Abstract

This doctoral thesis consists of four scientific studies that employ various research methodologies to achieve previously defined objectives. Firstly, two systematic reviews are presented to summarize and analyze the available scientific evidence on physical demand (Publication I) and physiological response (Publication II) in women's basketball. The purpose of these two works is to provide a comprehensive reference view of the tools available for load monitoring. Secondly, the scientific study of training load monitoring (Publication III) is included, conducted with young high-level basketball players (n = 13), where the relationship between load constructs, physical demand, and physiological response was examined. Finally, a research protocol (Publication IV) is included, involving the monitoring of official competition in a semi-professional team composed of adult players (n = 12). This study aims to analyze the relationship between physical demands measured through inertial sensors and performance indicators inherent to the game, as reported in statistics. This relationship could enhance the understanding of load values in cases where such devices are not available.

As a result of the systematic reviews, a total of 40 scientific publications were included in the case of external load study (Publication I), and 44 in internal load monitoring (Publication II). Firstly, publications that monitored external load studied demands during training (n = 11), matches (n = 20), or both events (n = 9). Among all the reported methods, inertial sensors were predominantly used (n = 28/40), with a sampling frequency of 100 Hz, placed on the upper back. However, a wide variety of metrics was observed, with the Player Load (PL), expressed in arbitrary units (UA), being a notable one. The different studies analyzed revealed that players at higher competitive levels exhibit higher physical demands, emphasizing the importance of players' conditioning as a central pillar of their performance during competition. Regarding the quantification of load during training, a broad range of load values was observed (PL 5x5: 34.8 ± 8, PL 3x3: 47.6 ± 7.4 UA, distance 5x5: 209.2 ± 35.8 m, and distance 3x3: 249.3 ± 2.8 m), making it challenging to draw precise conclusions. Despite this, it was noted that non-defensive tasks appear to be less demanding than those involving opposition, irrespective of the studied population. On the other hand, in the internal load study (Publication II), methods based on the subjective perception of effort (RPE) were most commonly used (n = 28/44), followed by heart rate monitoring (HR) (n = 27/44). In the case of the former, the 1-10 point scale was the most common, while HR quantification mainly involved reporting mean HR values, minimum and maximum HR, the percentage of maximum HR, and the time the player's heart spent in these relative pulsations. It was highlighted that training's mean HR had a wider range of values than during competition, as the heart responds with higher frequencies during the intense nature of the game. Finally, it is worth noting that none of these publications included meta-analyses due to data heterogeneity, which limited comparisons between the results obtained. However, a methodological quality analysis of the studies was conducted, resulting in scores considered fair or good when using the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) evaluation guide.

Regarding the results of the training load study (Publication III), a broad range of values was observed concerning external load, assessed through total accelerations (1767.0 ± 385.5), maximum total accelerations (258.0 ± 82.2), and maximum accelerations (8.4 ± 1.2) and decelerations (8.4 ± 1.2) per minute. On the other hand, the relationship between demand and response showed strong correlation levels when linking the total accelerations with Banister training impulses (0.8), a phenomenon explainable as both could be considered volume metrics. As for the remaining results, the correlation of total accelerations with sum zone HR models (SHRZ) and the player's subjective perception during the session (sRPE) were highlighted, showing a large relationship (0.6 in both cases). Finally, concerning intensity metrics, the total of maximum accelerations had a moderate association (0.4) with methods that monitored internal load (SHRZ and sRPE).

The results of this doctoral thesis offer a comprehensive understanding of the current state of methods, metrics, and reference values in monitoring load in women's basketball. This insight enables the enhancement and optimization of training and competition load. In the future, researchers and sports clubs must work to establish consensus regarding the utilization of the presented references. However, the unique characteristics of female athletes, particularly hormonal fluctuations in the menstrual cycle, which impact various physiological markers and subjective perception of load, should be considered.

Keywords: women's basketball, load monitoring, performance, physical demand

PREFACIO

En el mundo del deporte, la búsqueda constante de la mejora del rendimiento es un desafío que se renueva con cada entrenamiento, competición y temporada. En particular, el baloncesto femenino, en sus distintas modalidades y niveles competitivos, representa un escenario en constante evolución donde la ciencia y la tecnología se entrecruzan con la pasión y la dedicación de las deportistas. Esta tesis doctoral surge de la profunda convicción de que comprender los métodos para la monitorización de la carga en el baloncesto y los factores que la modulan, teniendo siempre en cuenta las características propias de la mujer deportista, es un paso imprescindible para que la jugadora alcance su mejor rendimiento.

La semilla de esta investigación se plantó al aterrizar en la ciudad de Barcelona, y ha germinado con el riego constante de la curiosidad y la determinación por explorar las complejas relaciones que existen entre la teoría y la práctica al tratar de cuantificar las demandas y la respuesta de un deporte que combina de forma única las destrezas técnicas y tácticas con un alto nivel de condición física. Desde los movimientos más precisos hasta el desempeño físico más intenso, el baloncesto femenino es un escenario en el que se puede apreciar la excelencia en cada acción.

Este prefacio pretende invitar al lector a recorrer el pequeño, pero intenso, viaje del estudio de la carga en este maravilloso deporte, descubriendo los métodos y métricas propuestas en la actualidad, estudiando sus cifras y comprendiendo la relación que guarda la dosis con la respuesta. A lo largo de las páginas que siguen, se mostrarán los resultados de cuatro estudios científicos. A través de estos estudios, en los cuales se ha revisado la evidencia actual y se han monitorizado a deportistas, se pretende aportar una visión cercana de algunas de las problemáticas del día a día de jugadoras, entrenadores y científicos del deporte, y dar paso a nuevas preguntas que deberán ser respondidas en el futuro.

Adentrémonos juntos en el mundo de la monitorización de la carga en el baloncesto femenino. Sin más preámbulos, te invito a sumergirte en esta tesis doctoral sobre baloncesto femenino, donde la ciencia se une al juego, y juntos exploraremos algunas de las fronteras del conocimiento.

Esperemos que este sea el inicio de un nuevo e ilusionante camino

CAPÍTULO 1

INTRODUCCIÓN

Baloncesto femenino: características, demandas y rendimiento

El mapa no es el territorio

Alfred Korzybski

El baloncesto se remonta a apenas dos siglos atrás (1891, escuela Young Men's Christian Association), naciendo como una solución deportiva a los períodos del año más fríos y lluviosos. Se extendió rápidamente por los Estados Unidos de América y Canadá, tanto entre hombres como mujeres. El primer partido oficial femenino se disputó en el Smith College de Northampton (Massachusetts, Estados Unidos), en 1893 (Porter, 2005). Actualmente, es uno de los deportes más populares en todo el mundo entre las mujeres, tanto por el número de practicantes como de seguidores. Un interés que ha llevado a investigadores y clubes deportivos a estudiar en detalle el baloncesto femenino, tanto en los niveles competitivos más altos como en las jugadoras jóvenes (Reina, 2020). A continuación, se describirán, a través de la revisión de la literatura científica disponible, las características propias del propio deporte y de sus participantes.

1.1. El baloncesto femenino

En el momento de la redacción de esta tesis doctoral encontramos dos modalidades ampliamente practicadas en todo el mundo. El baloncesto tradicional (5x5 en adelante) y el baloncesto 3x3 (3x3 en adelante), los cuales enfrentan a dos equipos de cinco y tres jugadoras cada uno respectivamente, cuentan con normativas diferentes, en especial en las dimensiones del terreno de juego y la gestión del tiempo (International Basketball Federation, 2023). La comprensión de estas dos diferencias es clave en el estudio de las exigencias del deporte y las características de las jugadoras. Ambas modalidades cuentan con situaciones de oposición e invasión en un espacio compartido y en el que los equipos se alternan la posesión de la pelota, lo que convierte al baloncesto en una práctica de continuo cambio y de incertidumbre permanente.

En relación al espacio, el 5x5 se juega en un terreno de 28 m de largo por 15 m de ancho, lo que supone una superficie de 420 m^2, un área de 42 m^2 a cubrir por cada jugadora. En el caso del 3x3 se dispone de un largo de 11 m por un ancho de 15 m, lo que modifica el área total de juego (165 m^2) y la que corresponde a cada jugadora (27,5 m^2). Por otro lado, se destaca como diferencia el reglamento del tiempo. En el 5x5 la duración total es de 40 minutos, tanto en competiciones de la *International Basketball Federation* (FIBA) como de la *Women's National Basketball Association* (WNBA), divididos en cuatro períodos de 10 minutos. Los partidos en el 3x3 duran 10 minutos, a excepción de si uno de los dos equipos anota 21 puntos, lo que hace terminar en ese instante el partido (International Basketball Federation, 2023). También las posesiones difieren en duración. Mientras que el 5x5 tiene una duración máxima de 24 segundos, el 3x3 cuenta con la mitad (12 segundos). Adicionalmente, en el 5x5 se disponen de más pausas en el reloj, especialmente a través de los descansos entre períodos, la petición de tiempos muertos, etc., lo que no ocurre en la modalidad 3x3. A continuación, se describirán las características, las demandas y respuestas de la jugadora de baloncesto.

1.2. Características de la jugadora de baloncesto

Es esencial aclarar que el rendimiento en el baloncesto es multifactorial, pese a ello, las características de la jugadora se identifican como un elemento central. Además del adecuado desarrollo de las habilidades técnicas específicas y el conocimiento táctico, se suman las características antropométricas y de maduración (Drinkwater et al., 2008), así como las capacidades condicionales y las características fisiológicas (Scanlan et al., 2012).

1.2.1. Maduración y antropometría

El ritmo de maduración, las características antropométricas y la composición corporal son aspectos relevantes a considerar en la selección del talento en el baloncesto femenino (I. A. Bayios et al., 2006). Se ha observado que las jugadoras con una maduración biológica prematura, una mayor altura, envergadura y alcance vertical presentan mayores probabilidades de alcanzar un mayor nivel competitivo (Torres-Unda et al., 2016), ya que se han relacionado con un mayor alcance, capacidad para bloquear tiros y facilidad para el rebote (Ziv & Lidor, 2009). En la Tabla 1 se observa como las ligas profesionales en Estados Unidos de América y Europa presentan en promedio alturas similares, independientemente del rendimiento final. A pesar de esto, se identifica que la WNBA cuenta con jugadoras más altas al segregar estas por posiciones.

Tabla 1

Promedio de Altura (cm) por Ligas, Rendimiento y Posiciones en las tres últimas temporadas (2020-2023)

Liga	Promedio	Rendimiento final		Posiciones		
		Finalistas	Campeón	Bases	Exteriores	Interiores
WNBA	182,7	184,3	182,1	179,1	189,6	197,1
EL	182,8	183,8	184,0	176,1	185,9	192,1
LF	182,5	182,8	184,7	175,9	184,4	191,9

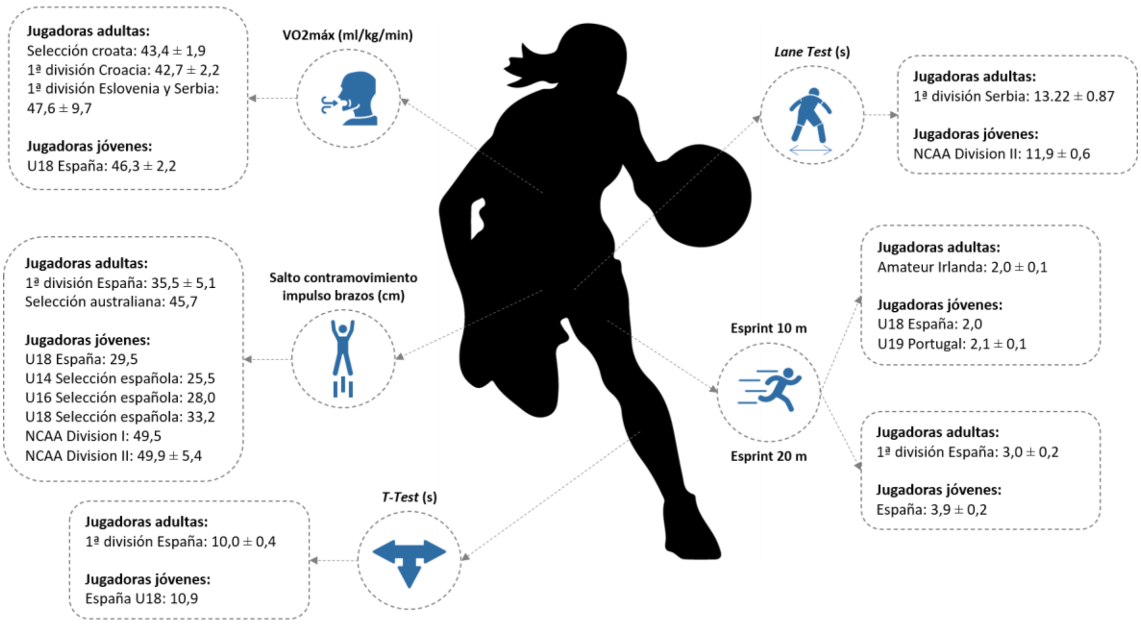
Nota. WNBA: *Women's National Basketball Association* (1ª División Baloncesto en Estados Unidos de América); EL: Euroliga (1ª División Baloncesto en Europa); LF: Liga Femenina (1ª División Baloncesto en España). Datos extraídos de la página web de la WNBA, 2023 (www.wnba), *Women's Euroleague* 2023 (www.fiba.basketball/euroleaguewomen) y la Federación Española de Baloncesto, 2023 (www.feb.es).

1.2.2. Capacidades condicionales

El baloncesto femenino demanda altos niveles de condición física con una predominancia de acciones de alta intensidad, un aspecto que destacan Schelling y Torres (2019) al describir la relación entre el rendimiento y el estado de forma en el baloncesto. Estos autores señalan que para obtener un mayor rendimiento es necesario: 1) correr más rápido y saltar más alto que tu rival; 2) disponer de mayores niveles de fuerza y estabilidad para resistir los contactos físicos e impactos durante el juego; y 3) tolerar las demandas físicas del juego con un nivel de fatiga menor que el de tu rival (Schelling & Torres, 2016). Por lo que es común que entre las pruebas utilizadas para evaluar la condición física de la jugadora de baloncesto destaquen las relacionadas con: a) la potencia aeróbica; b) la capacidad anaeróbica; c) la potencia del miembro inferior; d) la velocidad; e) la agilidad; f) y la fuerza (Mancha-Triguero et al., 2019). En base al conocimiento disponible en el estudio de las capacidades condicionales de la jugadora de baloncesto se resumen en la Figura 1 algunos valores de referencia por grupos de edad en diferentes pruebas.

Figura 1

Valores de referencia de las diferentes capacidades condicionales a través de diferentes test de rendimiento físico en jugadoras adultas y jóvenes



Nota. Datos extraídos de diferentes publicaciones: Arede et al., 2021; Drinkwater et al., 2007; Fort-Vanmeerhaeghe et al., 2016, 2022; Garcia-Gil et al., 2018; Jeličić et al., 2020; Mancha-Triguero et al., 2021; Scanlan et al., 2021; Woolstenhulme et al., 2004; Zaragoza et al., 2022

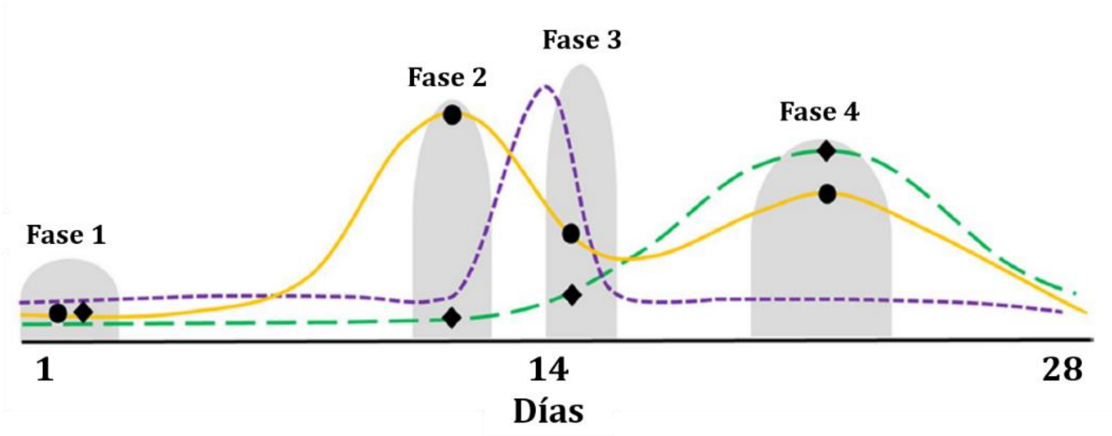
1.2.3. El ciclo menstrual y la mujer deportista

La mujer deportista como sujeto de estudio en la investigación tiene una baja presencia (Costello et al., 2014), un fenómeno que se acentúa al segregar por niveles competitivos (Noordhof et al., 2022; Sandbakk et al., 2018). En 2019, Iñigo Mujika traslada la preocupación de no disponer de literatura científica que tenga en cuenta las características específicas de la fisiología de la mujer, la cual es única debido al complejo ciclo hormonal que regula el ciclo menstrual (Mujika & Taipale, 2019), dificultando así la comprensión de las necesidades específicas de la mujer deportista. Además, la evidencia científica disponible sobre los factores específicos de la mujer deportista se fundamenta principalmente en disciplinas deportivas de carácter individual, por lo que no se han considerado en profundidad las características, experiencias y percepciones de las mujeres que compiten en deportes de equipo y, por tanto, en el baloncesto (Findlay et al., 2020). A pesar de esto, conocerlas favorecerá mejoras en el proceso de entrenamiento, y probablemente también en el rendimiento durante la competición (Bassett et al., 2020).

La principal característica fisiológica de la mujer deportista es la presencia del ciclo menstrual entre las épocas de la pubertad y la menopausia. Un ciclo en el que, en condiciones normales, ocurren grandes fluctuaciones de estrógenos y progesterona en períodos de 21 a 35 días de duración a lo largo de diferentes fases de diferentes duraciones (Elliott-Sale et al., 2021). Estas variaciones en las concentraciones hormonales circulantes son afectadas por un conjunto de factores: a) externos: uso de anticonceptivos hormonales, ritmos circadianos, ejercicio físico, la dieta, estrés, etc.; b) condiciones clínicas: amenorrea hipotalámica, síndrome ovarios poliquísticos; c) el embarazo (Constantini et al., 2005; Savage & Clarkson, 2002). Y aunque el efecto de las diferentes fases del ciclo sobre el entrenamiento y el rendimiento no parece estar aún claro, la evidencia disponible señala que las fluctuaciones hormonales sí que podrían interferir en la percepción propia de la deportista al esfuerzo, las adaptaciones fisiológicas y el rendimiento (McNulty et al., 2020). Fenómenos que han hecho considerar los picos de concentración hormonales y su duración como herramientas en la comprensión de la respuesta al entrenamiento y el rendimiento (Duggan et al., 2021; Elliott-Sale et al., 2021).

Figura 2

Cinética hormonal durante el ciclo menstrual y sus fases en una mujer eumenorréica



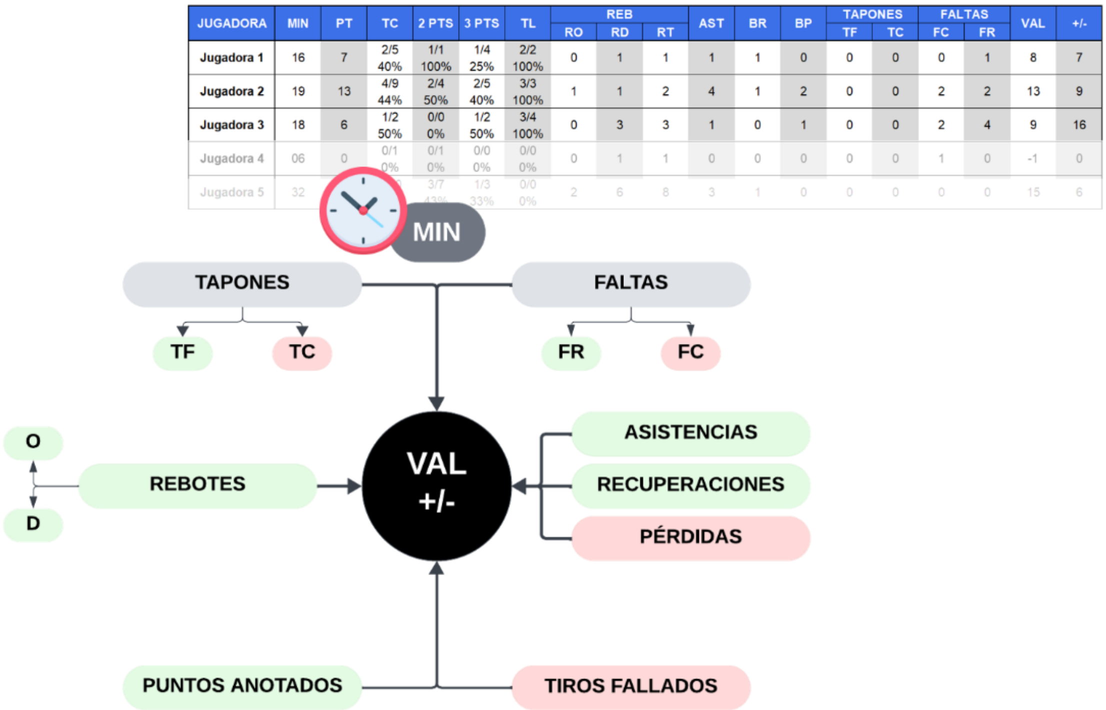
Nota. Estrógenos: línea amarilla; Progesterona: línea verde; LH: línea morada. Fase 1: menstruación (días 1 al 5); Fase 2: folicular (días 1 al 12); Fase 3: ovulatoria (días 12 al 15); Fase 4: lútea (días del 16 al 28). Adaptado de: *Visual overlay of the hormonal changes across an idealized 28-day menstrual cycle indicating when each phase begins and ends*, de Elliot-Sale et al., 2021.

1.3. Parámetros de rendimiento en el baloncesto femenino

En la evaluación del rendimiento está ampliamente extendido el análisis de las acciones específicas, donde las acciones se categorizan como positivas (puntos, rebotes, asistencias, faltas recibidas y tapones) o negativas (número de tiros fallados, faltas cometidas y balones perdidos) (Figura 3). La diferencia entre las acciones positivas y negativas es lo que se denomina valoración o eficiencia. Y a esta se le añade el parámetro +/-, que indica la diferencia de anotación entre los dos equipos en el período de tiempo que una jugadora está en pista.

Figura 3

Esquema de los elementos evaluados en la estadística tradicional del baloncesto y su relación con la valoración final del rendimiento



Nota. En verde elementos que suman valoración positiva y en rojo negativa.

En los últimos años, basándose en la anotación de estas métricas en el análisis del juego, se ha desarrollado la estadística avanzada, la cual ha centrado sus esfuerzos en relativizar estos datos, por posesiones jugadas, minutos, cantidad total de acciones (como el total de tiros del equipo) y la participación individual o colectiva. Entre estas métricas se han destacado las ratios ofensivas y defensivas, que evalúan la eficiencia de un equipo en la faceta de ataque y defensa, calculando el número de puntos anotados/recibidos por cada 100 posesiones del equipo. A través de datos obtenidos de las páginas webs de las ligas, se muestra en la Tabla 2 la comparativa de estas métricas en diferentes ligas de máximo nivel. Observándose que a mayor nivel competitivo mayor eficiencia en el tiro.

Tabla 2

Promedio de Ratio Ofensivo y Ratio Defensivo en diferentes Ligas Profesionales durante las tres últimas temporadas (2020-2023)

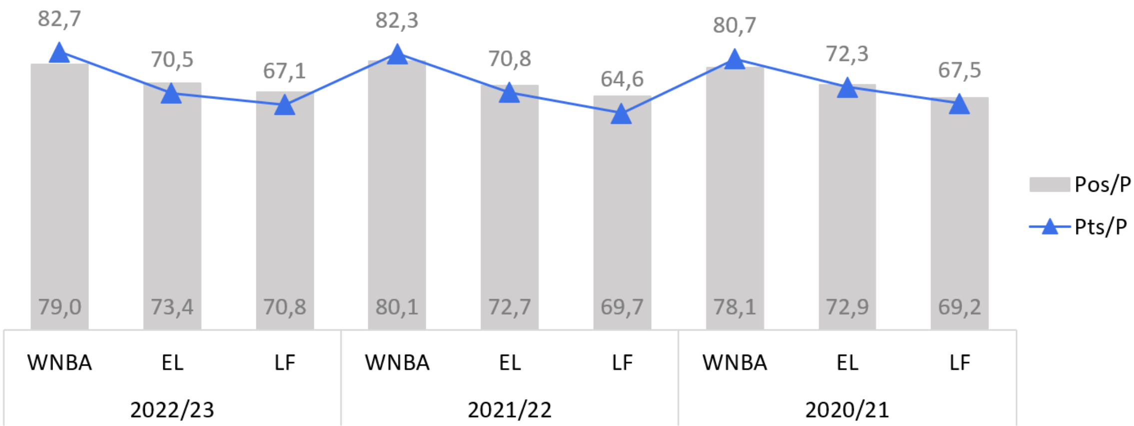
Liga	Ratio Ofensivo	Ratio Defensivo
WNBA	128,9	100,0
EL	97,5	99,3
LF	95,0	96,1

Nota. WNBA: *Women's National Basketball Association* (1ª División Baloncesto en Estados Unidos de América); EL: Euroliga (1ª División Baloncesto en Europa); LF: Liga Femenina (1ª División Baloncesto en España). Datos extraídos de la página web de la WNBA, 2023 (www.wnba), *Women's Euroleague* 2023 (www.fiba.basketball/euroleaguewomen) y la Federación Española de Baloncesto, 2023 (www.feb.es).

Aunque algunas publicaciones han estudiado la relación de estas métricas con las demandas, no se han reportado relaciones fuertes entre variables de estadística tradicionales y las demandas físicas (J. Fox et al., 2022; García, Fernández, et al., 2022). Alternativamente, relativizar estas acciones al número de posesiones o minuto disputado podría esclarecer la relación entre el rendimiento y la carga. Un ejemplo de esto podría ser la métrica del ritmo de juego (número de posesiones jugadas por cada equipo), la cual informa sobre cuántas veces se intercambia la posesión. A modo de ejemplo, al comparar el ritmo de juego de diferentes ligas se observó que los equipos de la WNBA, en promedio, disputan un mayor número de posesiones que en la Euroliga o la Liga Femenina en España, en la misma cantidad de tiempo. Lo que podría indicar que las jugadoras de mayor nivel presentan una mayor demanda física. Veamos a continuación, de forma resumida, qué requerimientos condicionales presenta el baloncesto femenino y su relación con el nivel competitivo.

Figura 4

Evolución del número de posesiones y puntos por partido en tres ligas diferentes durante las tres últimas temporadas



Nota. WNBA: *Women's National Basketball Association* (1ª División Baloncesto en Estados Unidos de América); EL: Euroliga (máxima categoría baloncesto en Europa; LF: Liga Femenina (1ª División Baloncesto en España); Pos/P: posesiones por partido; Pts/P: puntos por partido. Datos extraídos de la página web de la WNBA, 2023 (www.wnba), Women's Euroleague 2023 (www.fiba.basketball/euroleaguewomen) y la Federación Española de Baloncesto, 2023 (www.feb.es).

1.4. Demandas físicas del baloncesto femenino

Las características del baloncesto lo hacen dinámico y exigente, con una elevada presencia de acciones de alta intensidad, como esprints, saltos, aceleraciones y deceleraciones en diferentes planos, cambios de dirección, etc., a lo largo de un tiempo prolongado (McInnes et al., 1995). Este hecho requiere de una aportación energética producida por diferentes vías metabólicas, donde la mayor cantidad de esta energía aportada por las vías oxidativas a pesar de ser los procesos glucolíticos los que permiten las acciones de alta intensidad, siendo estas destacadas como las acciones determinantes en el baloncesto (Montgomery & Maloney, 2018; Oliveira-Da-Silva et al., 2013). Además de estos requisitos condicionales, debemos añadir la sincronicidad con la pelota, las compañeras y las oponentes, la necesidad del dominio de habilidades específicas del movimiento (tiro, pase, *dribbling*, etc.) y el conocimiento de situaciones tácticas (Ostojic et al., 2006; Ziv & Lidor, 2009).

Algunos autores han reportado, a través del análisis en vídeo, que la mayoría de acciones que realiza una jugadora durante la competición se identifican como estar de pie o caminar, debido principalmente a las interrupciones propias del juego (Conte et al., 2015; Matthew & Delextrat, 2009; Scanlan et al., 2012). Estos instantes breves permiten a la deportista recuperarse de esfuerzos de alta intensidad. Es por ello que se ha destacado la importancia del sistema cardiovascular en la movilización de sustratos y desechos metabólicos en los músculos (Abdelkrim et al., 2007). Una hipótesis respaldada al observar los valores de frecuencia cardíaca (FC) promedio a lo largo del partido, la cual se mantiene en valores superiores a 160 pulsaciones por minuto, indicando un trabajo continuo del sistema cardio-respiratorio, tanto en el 5x5 (Matthew & Delextrat, 2009; Reina Román et al., 2019; Scanlan et al., 2012), como en el 3x3 (Willberg et al., 2023). Este es un punto clave en la comprensión de las demandas del deporte y un motivo por el que se ha señalado que una mayor condición aeróbica favorece un mayor rendimiento físico (Narazaki et al., 2009).

A pesar de esto, las acciones que han sido identificadas como determinantes en el rendimiento son las que dependen en mayor medida de procesos glucolíticos, como los esprints, saltos, cambios de dirección e impactos (Schelling & Torres, 2016). Y se ha observado que estas acciones no ocurren con la misma frecuencia en todos los niveles competitivos. En el caso del 5x5, analizado a través de vídeo, algunos autores han reportado una frecuencia de acciones de alta intensidad en jugadoras amateurs de 58 ± 19 (Matthew & Delextrat, 2009). Estos valores parecen ser menores en jugadoras profesionales y élite, con 28,6 ± 17,5 y 25 ± 10 respectivamente (Conte et al., 2015; Delextrat et al., 2012). El número de saltos son un claro ejemplo. Se ha observado que jugadoras amateurs parecen realizar un mayor número de saltos (Scanlan et al., 2012) en comparación con jugadoras de mayor nivel (Oliveira-Da-Silva et al., 2013), 43 ± 6 respecto a 23 ± 6,2. Algo similar a lo que se ha observado con el uso de unidades de movimientos inerciales (IMU, siglas en inglés) donde las jugadoras amateurs (Reina et al., 2017) reportaron más saltos por minuto que las jugadoras profesionales (Reina et al., 2022), 1,8 ± 0,4 vs 0,7 ± 0,3.

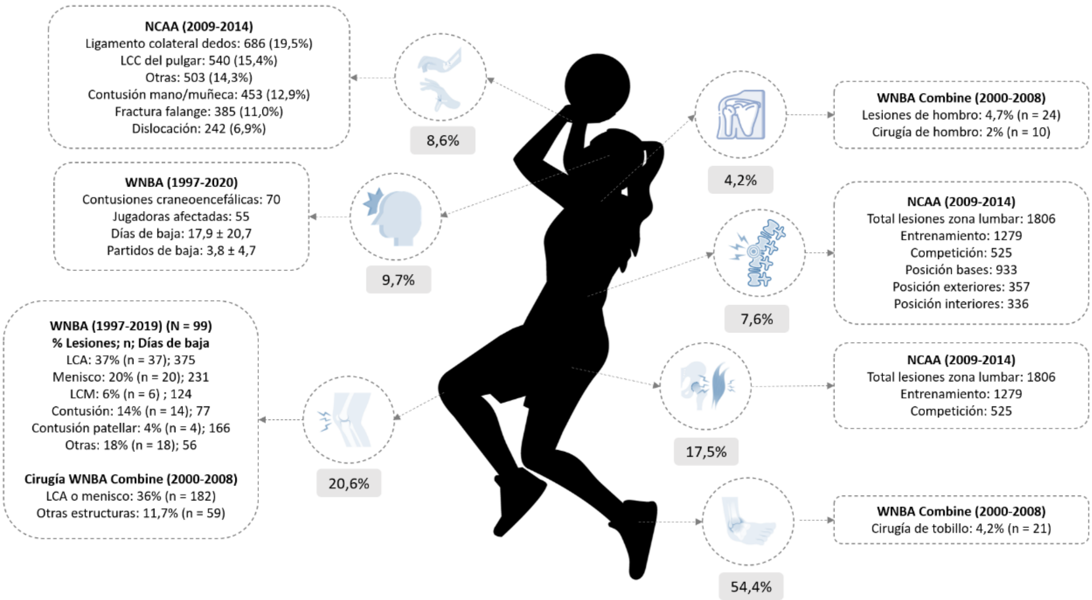
En relación al rendimiento y cómo este se relaciona con la carga, un mayor nivel competitivo en el baloncesto femenino parece mostrar una mayor demanda física, en especial en lo relativo a la densidad de acciones (Figura 4). Datos obtenidos a través de IMU indican que las jugadoras consideradas nivel élite exhiben valores mayores de carga (evaluada a través de la variable de *Player Load,* PL) por minuto que las de menor nivel (4,6 ± 2.0 vs 2,8 unidades arbitrarias, UA en adelante) (Coyne et al., 2021; Reina et al., 2019).

1.5. Lesiones en el baloncesto femenino

Una revisión sistemática reciente estudió las publicaciones científicas sobre epidemiología lesional del baloncesto entre los años 2008-2018. Se incluyeron en el análisis 11 publicaciones, con un total de 4291 lesiones reportadas en el baloncesto femenino, observándose que las regiones anatómicas de mayor incidencia lesional se encuentran en el miembro inferior, siendo el tobillo y el pie (49,8%), la rodilla (20,6%) y la región del muslo, cadera y pierna (17,5%) las zonas más afectadas independientemente del nivel competitivo. En el caso del miembro superior las lesiones más frecuentes se observan en manos y dedos (8,6%) (Andreoli et al., 2018).

Figura 5

Incidencia de lesiones en el baloncesto femenino



Nota. En los recuadros de color gris se presentan datos de incidencia lesional general de la región anatómica señalada. Datos extraídos de Andreoli et al., 2018. En los recuadros con bordes punteados se presentan datos de incidencia de lesiones estudiados en diferentes poblaciones. Datos extraídos de diversas fuentes: Andreoli et al., 2018; Axelrod et al., 2022; Makovicka et al., 2019; McCarthy et al., 2013; Walker et al., 2022.

Otras publicaciones han destacado que entre las lesiones de rodilla la rotura de ligamento cruzado anterior (LCA) se ha reportado como la más común en el baloncesto femenino de élite, seguida esta por rotura de menisco y lesiones del ligamento colateral medial (Axelrod et al., 2022). La lesión de LCA se ha relacionado en la literatura a mecanismos específicos en el aterrizaje del salto (flexión cadera y valgo de rodilla), con un riesgo aparentemente mayor en las jugadoras que ocupan la posición de base, suponiendo además un menor número de partidos y minutos jugados y un peor rendimiento (reducción significativa en porcentaje de tiros libres y tiros de tres puntos) al menos el primer año de competición tras la lesión (Tramer et al., 2020).

En el caso de las jugadoras jóvenes se observa una incidencia similar en diferentes poblaciones, siendo la rodilla, el pie y el tobillo las regiones que presentan más lesiones (Andreoli et al., 2018). Un estudio, que recopiló las lesiones de 200 jugadoras jóvenes canadienses, mostró una incidencia de 13,8 lesiones por cada 1000 horas de exposición. Las localizaciones con mayor afectación fueron el tobillo (45,1%) y la rodilla (36,4%). Y entre los tipos de lesión la más recurrente fue la lesión ligamentosa (63%) (Owoeye et al., 2020). Hallazgos similares a los reportados por los servicios de urgencias de Estados Unidos de América durante la década de 2010-2020 (Houlihan et al., 2023), por el sistema nacional de vigilancia de lesiones de Estados Unidos de América en el período 2012-2018 (Zynda et al., 2022) y por otros autores europeos (Peña et al., 2023). En la disminución de la incidencia lesional, en los últimos años, se ha resaltado la importancia de un adecuado proceso de monitorización y gestión de la carga como un elemento central (Coles, 2018; Gabbett, 2016).

La monitorización de la carga

> Es mucho lo que se puede
> observar solo mirando
>
> Yogi Berra

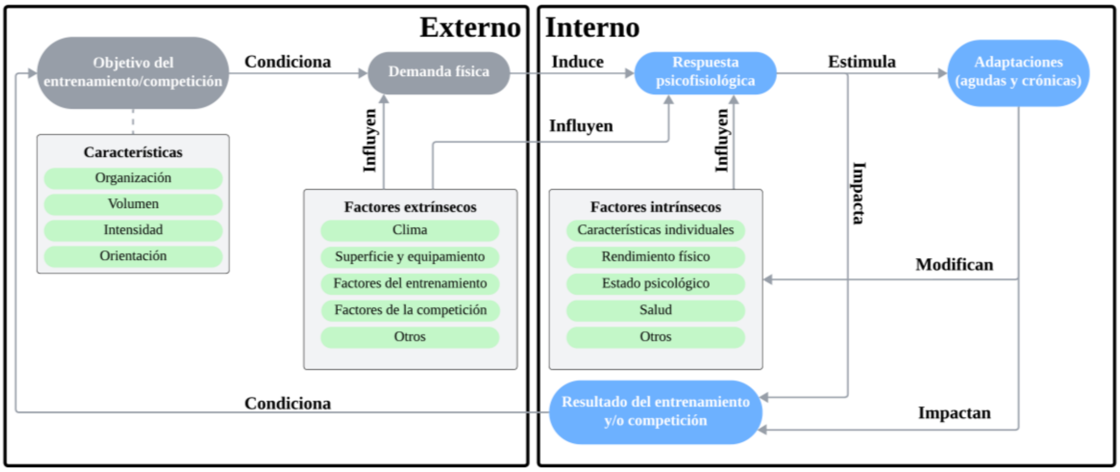
Las ciencias del deporte han mostrado un interés especial por el concepto de carga de entrenamiento o trabajo a lo largo de las últimas décadas (Impellizzeri et al., 2019). Su monitorización y gestión persigue dos objetivos que se relacionan: 1) optimizar el proceso de entrenamiento, facilitando y promoviendo las adaptaciones fisiológicas deseadas para la disponibilidad y el adecuado rendimiento de los deportistas; y 2) la prevención de lesiones, anticipando, a través de los datos recogidos, posibles escenarios de mayor riesgo (García, Schelling, et al., 2022). Además, la monitorización y control de la carga es un aspecto clave en los procesos de rehabilitación y readaptación de lesiones (Bourdon et al., 2017; Halson, 2014). Y aunque la selección de los métodos utilizados para la cuantificación de la carga es dependiente de cada contexto específico (Buchheit & Laursen, 2013), la recopilación de estos datos posibilita una mejor planificación en cinco niveles diferentes: 1) diaria; 2) semanal o de microciclo; 3) período competitivo; 4) temporada; 5) largo plazo (West et al., 2021).

2.1. El concepto de la carga

La definición de este concepto ha evolucionado a lo largo del tiempo. En la actualidad existe un amplio consenso de que este término se compone de dos constructos (Impellizzeri et al., 2019). El primero es la demanda física o carga externa, la dosis a la cual se expone al deportista. Como respuesta a esta dosis aparece el segundo constructo, la respuesta psicofisiológica o carga interna (Bourdon et al., 2017; Vanrenterghem et al., 2017). Esta respuesta, individual y relativa, está influida por un conjunto de factores extrínsecos e intrínsecos que deben contemplarse (West et al., 2021). La Figura 6 representa de forma esquemática ambos constructos y su relación y los factores que deben ser tenidos en cuenta. En adelante, con el objetivo de facilitar la lectura, se utilizará el concepto de la carga para hacer referencia a ambos constructos, ya sea en eventos de entrenamiento o competición e incluyendo en este término la interacción con los diferentes factores contextuales.

Figura 6

Diagrama teórico de la relación entre la carga externa e interna

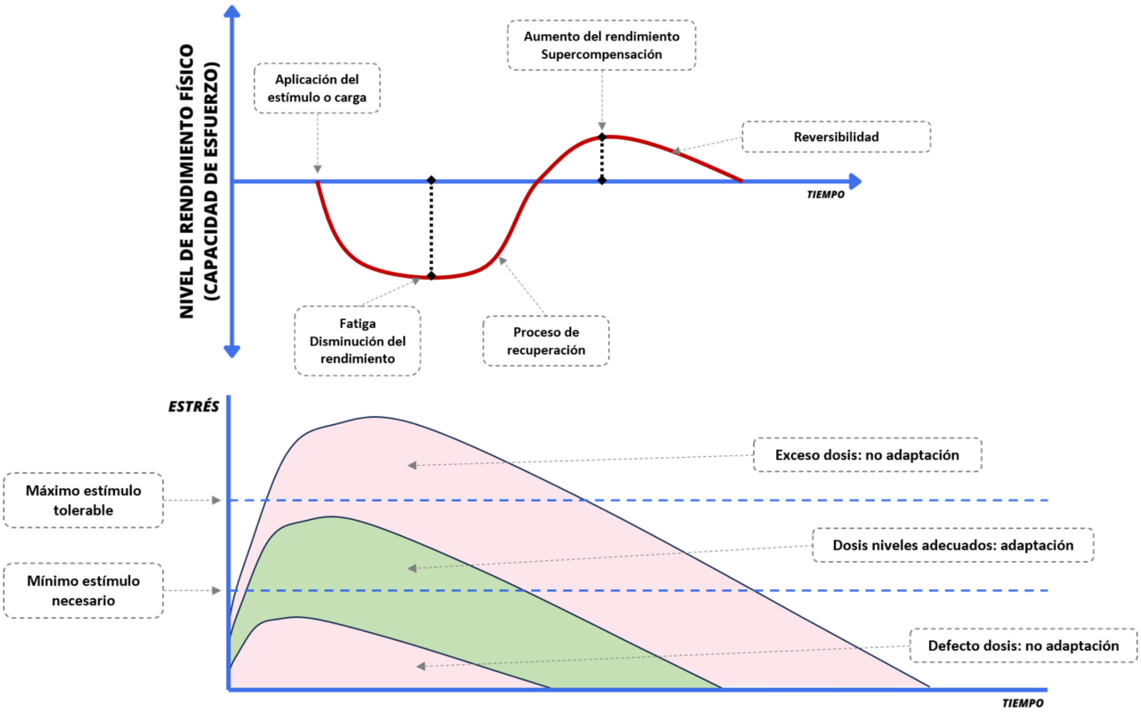


2.2. El binomio dosis-respuesta

La aplicación de una carga supone un estresor que altera la homeostasis de los sistemas corporales (Coffey & Hawley, 2007). Este desequilibrio se restituye con el tiempo, pero la persistencia e intensidad de sus efectos varía debido a la magnitud, duración y repetición del estímulo. Además, la carga sigue el principio de hormesis, donde la aplicación de dosis insuficientes o excesivas provocan una inhibición de la adaptación, e incluso podrían suponer pérdida de rendimiento, por exceso y defecto. En cambio, la estimulación en intensidad y momento adecuado provocará la respuesta deseada (Figura 7). Este efecto se conoce como el principio de super compensación descrito en la literatura (López Chicharro & Fernández Vaquero, 2008). Por este motivo que se propone la monitorización de la pérdida de rendimiento como un elemento clave a monitorizar (Bishop et al., 2023).

Figura 7

Principio de super compensación y hormesis.

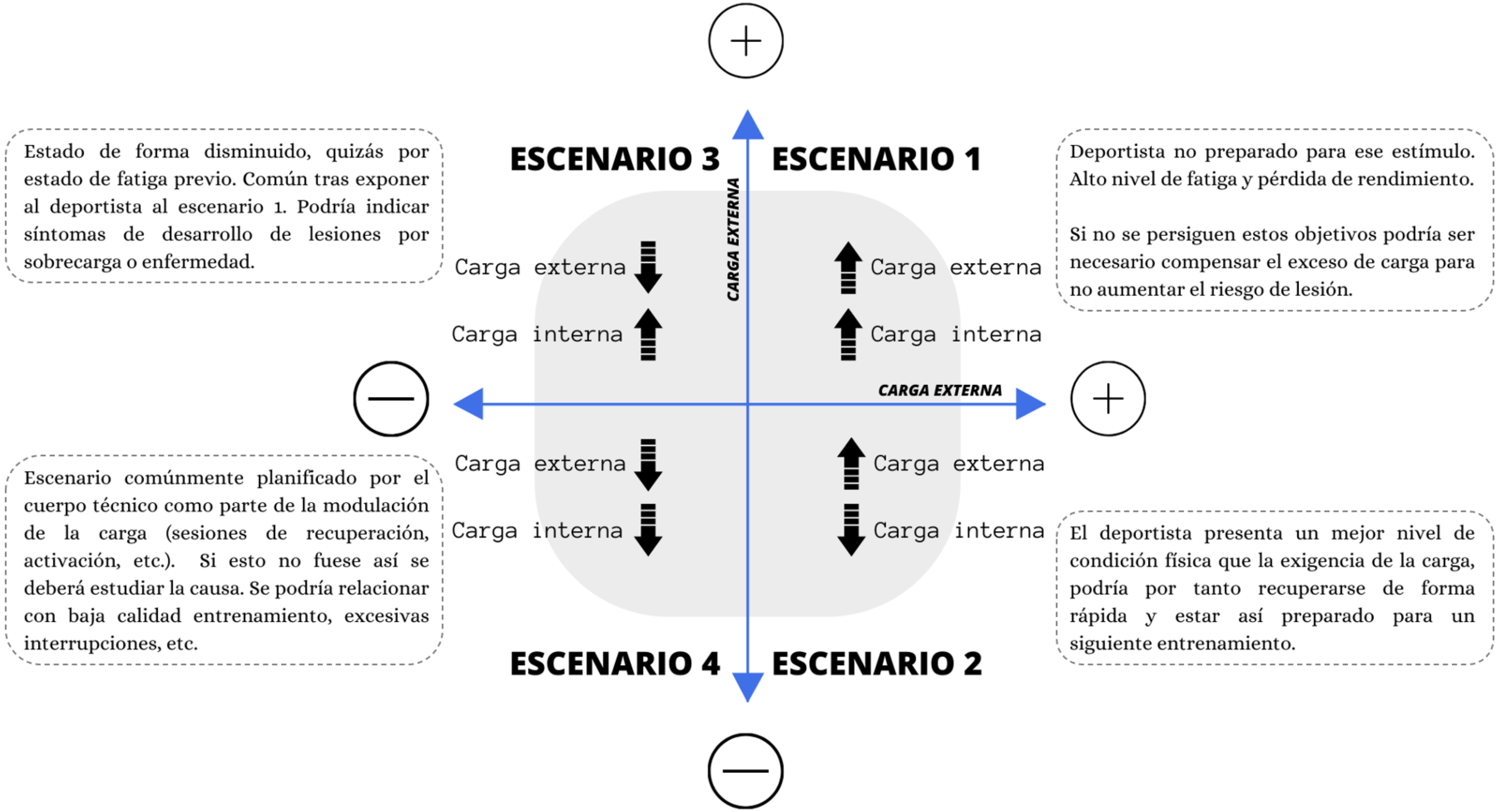


Nota. Arriba: principio de super compensación. Abajo: principio de hormesis.

Como resultado de la carga externa, los diferentes sistemas del organismo del individuo generarán una respuesta (Coffey & Hawley, 2007), ocurriendo esta en dos niveles temporales: inmediata (respuesta aguda) y adaptación a largo plazo (respuesta crónica). La magnitud, duración y repetición en el tiempo serán los factores que determinen la adaptación fisiológica posterior (Bartlett et al., 2017; Viru & Viru, 2000). Esta relación es individual y contextual. Es por ello que la evaluación de la relación entre carga externa e interna se convierte en un elemento clave, y en la que se han observado resultados diversos en los deportes de equipo (McLaren et al., 2018). A pesar de ello, existe un consenso en el que se reconocen diferentes escenarios al relacionar la demanda física con la respuesta interna individual de la jugadora, lo que podría orientar los procesos de entrenamiento al comprender cada uno de ellos (Figura 8).

Figura 8

Posibles escenarios en el estudio de la relación entre la carga externa y la carga interna



Nota. Adaptado de *Internal versus external load as represented by average heart rate and high-speed* running, de Burgess 2016.

2.3. Factores contextuales que impactan en la carga y la respuesta de la deportista

La exposición al entrenamiento y la competición es el principal componente de la carga que soporta la deportista, pero en ella impactan un conjunto de factores extrínsecos e intrínsecos los cuales se han propuesto tener en cuenta para una mejor comprensión de la respuesta de la deportista a la demanda física (Bourdon et al., 2017). A continuación, se destacan algunos de estos factores recomendados para contextualizar los valores de carga: factores ambientales, contextuales del equipo e individuales de la jugadora (West et al., 2021). Incluir estos elementos en el proceso de monitorización de la carga aportará información relevante para una mejor comprensión de las respuestas individuales.

2.3.1. Factores ambientales

En primer lugar, como factores extrínsecos, se han destacado las condiciones atmosféricas. Aunque el organismo cuenta con mecanismos fisiológicos propios para contrarrestarlos y mantener la funcionalidad, los entornos calurosos, fríos, húmedos o de hipoxia alteran el rendimiento físico y cognitivo (Paul et al., 2015). Estos procesos compensatorios suponen un aumento del coste metabólico y modifican la percepción del esfuerzo (Bergeron et al., 2012). Por cada 1ºC de descenso en la temperatura corporal central (TCC) se ha observado: a) disminución del rendimiento aeróbico por un menor consumo de oxígeno (VO_2), atribuyéndose este fenómeno a una disminución en la FC máxima de entre 10 a 30 latidos por minuto; b) menores niveles de fuerza y potencia; c) peor destreza manual por entumecimiento y pérdida de sensibilidad (Bubnis & Hulsopple, 2022; Castellani & Tipton, 2015). En el caso opuesto, el aumento de la TCC y cutánea, se asocia con procesos de deshidratación agudos y peores procesos de recuperación (O'Connor et al., 2020; Racinais et al., 2023). Estos entornos calurosos están asociados frecuentemente con valores elevados de humedad relativa, lo que dificulta la evaporación. Esto favorece un aumento de la condensación de la piel debido a la alteración en la conducción térmica entre esta y el entorno (López Chicharro & Fernández Vaquero, 2008). En estos ambientes calurosos se han reportado menores distancias a alta velocidad (-3.4%), una mayor actividad cardíaca (+ 3,9% de tiempo > 85% FC máxima), peor percepción del esfuerzo (+ 1,8 UA), alteración en la percepción del estrés tras 24 horas (- 0,11 UA) y peor calidad del sueño en las 48 horas posteriores (O'Connor et al., 2020).

Por otro lado, en altitud, el organismo se enfrenta a una situación hipobárica y de hipoxia, lo que provoca un aumento de la ventilación y la actividad cardíaca con el objetivo de compensar la disminución de oxígeno del ambiente (López Chicharro & Fernández Vaquero, 2008). Esta exposición se ha relacionado con un peor rendimiento físico, alterando la percepción de la carga y del bienestar, además de ralentizar los procesos de recuperación y la calidad del sueño (Girard et al., 2013). A modo de ejemplo, algunos autores han reportado reducciones significativas cercanas al 3% de la distancia total recorrida al disputar partidos por encima de los 1200 metros de altitud sin una adaptación previa (Nassis, 2013), un fenómeno que afecta principalmente a los equipos visitantes (Girard et al., 2013).

Finalmente, la contaminación atmosférica se ha destacado como un aspecto a tener en cuenta al observar que la inhalación de aire contaminado tiene efectos negativos sobre la salud de la deportista, su rendimiento y los procesos de recuperación tras la actividad, tanto en el corto como en el largo plazo (Beavan et al., 2023; Rundell, 2012). En especial se ha destacado la disminución de la función cognitiva, cardiovascular, respiratoria y urinaria (Laeremans et al., 2018), elevando así la carga interna de los deportistas y disminuyendo el efecto de las adaptaciones posteriores deseadas. Su monitorización por tanto podría ser un parámetro de interés a vigilar (Hung et al., 2023) al suponer una desventaja competitiva en algunos casos (Beavan et al., 2023).

2.3.2. Factores contextuales de la competición y el entrenamiento

Las dinámicas de competición y entrenamiento de un equipo a lo largo de la temporada presentan una multitud de elementos que impactan en la carga de la deportista, aunque, como veremos a continuación, algunos de estos son nada o poco modificables. En cualquier caso, disponer de esta información aporta una mejor comprensión de los datos de carga y facilita la toma de decisiones.

En la competición, la elección de titulares y suplentes y la planificación de las sustituciones (Castillo-Rodríguez et al., 2023), la posición o rol de la deportista (García et al., 2020), la táctica y la estrategia (Castillo et al., 2021) y el uso de los tiempos de descanso son algunos factores bajo el control del cuerpo técnico para modificar la carga de la deportista. Pero se debe tener en cuenta que hay muchos otros que son poco o nada modificables, como los resultados previos de la competición (Ponce-Bordón et al., 2021), el calendario y el tiempo transcurrido desde el último partido (Kempton et al., 2015), el marcador del partido actual (Ponce-Bordón et al., 2021) e incluso el próximo rival (Jiménez et al., 2012). Algunos de estos factores se han relacionado con cambios hormonales, incluso escenarios hipotéticos futuros, que pueden provocar respuestas anticipatorias de estrés alterando el normal funcionamiento de los sistemas cardiovascular y respiratorio y la propia percepción de la carga (Buchheit et al., 2023). Factores que no solo tendrán un impacto aislado en la competición, también influirán en las sesiones de entrenamiento, en especial a las más próximas realizadas a la competición, en las que el cuerpo técnico dispondrá de algunas herramientas para su gestión, en especial a través de la planificación de las variables de volumen, intensidad y densidad y el estilo de entrenamiento (Ekstrand et al., 2023). Aunque el momento de la temporada en el que se encuentre el equipo marcará la capacidad de actuación sobre la gestión de la carga, ya que se han observado alteraciones de los niveles hormonales en momentos avanzados de la temporada, tanto en jugadoras (Kamarauskas & Conte, 2022) como en jugadores (Martínez et al., 2010; Schelling et al., 2015) de baloncesto.

2.3.3. Factores intrínsecos de la deportista

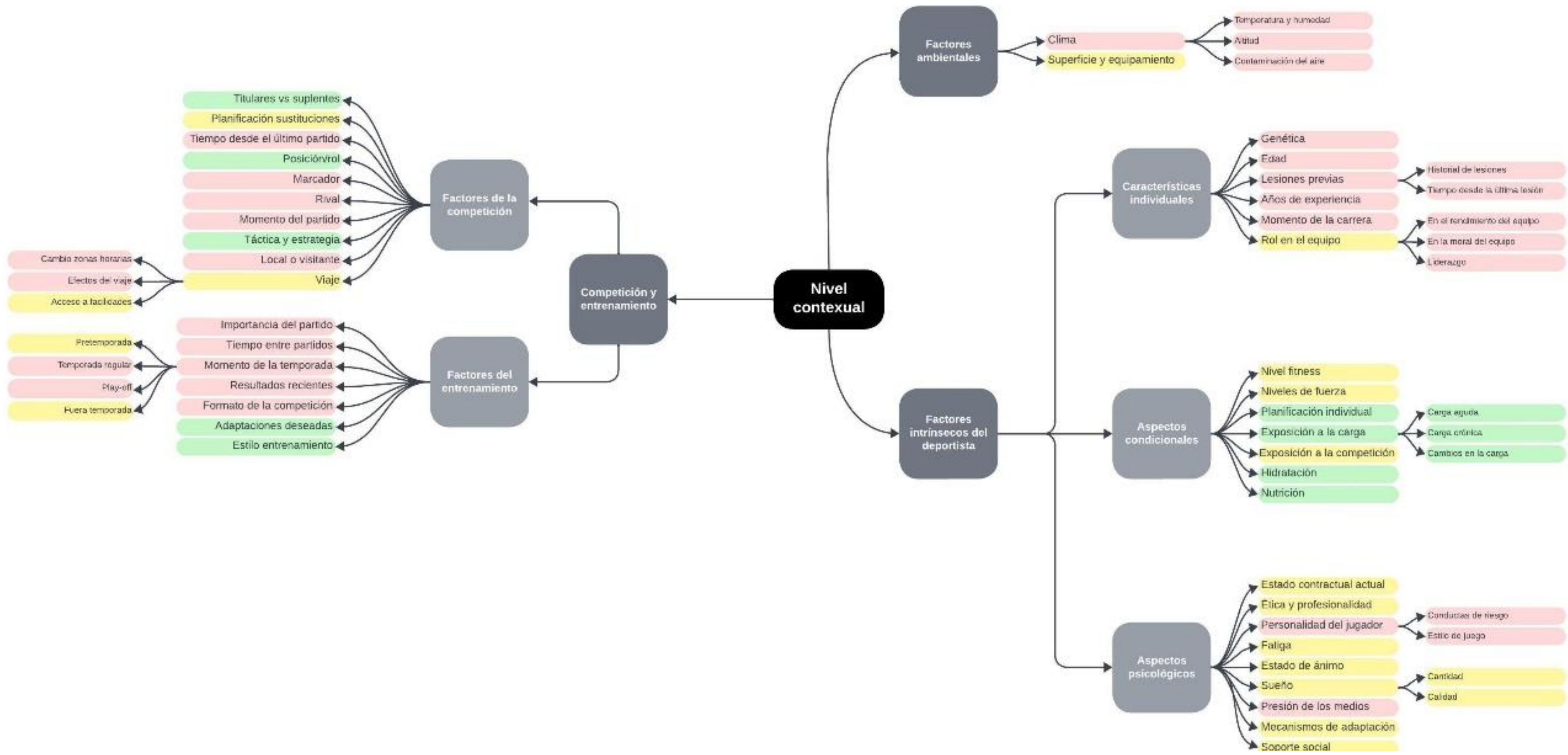
Hasta este momento se han identificado los factores externos y cómo estos influyen en los valores de carga. Sin embargo, serán los numerosos factores internos los que tengan una mayor relevancia en el desempeño físico y la respuesta fisiológica individual. Estos se pueden categorizar en: las características propias de la deportista, los aspectos condicionales y los aspectos psicológicos. En algunos de ellos es posible influir de forma total o parcial, mientras que otros directamente son inmodificables (Figura 9). Monitorizar y cuantificar cada uno de ellos se hace en muchos casos imposible, adquiriendo una importancia mayor la relación entre los profesionales y deportistas, con el fin de recabar información a través de conversaciones sinceras basadas en relaciones sólidas y de confianza mutua (West et al., 2021). A pesar de esto, a continuación, se destacan aquellos elementos que pueden ser monitorizados y tenidos en cuenta en la comprensión de los datos de carga.

Entre los factores no modificables que impactan en la carga se destacan principalmente la edad, la genética, la experiencia y el momento de la carrera deportiva. Mientras que una jugadora joven podría tolerar cargas más elevadas y con mayor frecuencia, las deportistas de mayor edad podrían no soportar estas demandas. Algo similar a lo que ocurre con las características genéticas y la experiencia en el entrenamiento (Gallo et al., 2015). Este es un primer punto que pone de manifiesto la necesidad de una aproximación individual al análisis de los datos (Jones et al., 2017). A pesar de estos condicionantes, existe una amplia evidencia científica que sostiene que mayores niveles de fuerza y de acondicionamiento cardiovascular y respiratorio ayudan a las deportistas a soportar cargas más elevadas y cambios repentinos de la carga (Drew et al., 2017; Gabbett et al., 2014; Rogalski et al., 2013), traduciéndose esto en una mayor disponibilidad y presencia en las sesiones de entrenamiento. Para lograr estos beneficios se propone la elaboración de una planificación individual, permitiendo así una exposición mayor de las jugadoras al entrenamiento y la competición, adaptándose a mayores volúmenes e intensidades, un hecho que generará un bucle de retroalimentación positiva. Y aunque este aspecto por sí solo no conlleva un aumento directo en el rendimiento de los equipos, una mayor disponibilidad de la plantilla sí que se ha relacionado con mejores resultados (Drew et al., 2017).

Además de los mencionados, existen un conjunto de factores intrínsecos que son relativamente modificables, como el estado psicológico y emocional de la deportista o el soporte social y aceptación del grupo (Watson et al., 2017), los cuales juegan un papel clave en cómo la deportista se enfrenta a las demandas físicas del entrenamiento y la competición (West et al., 2021). Asimismo, no podemos pasar por alto la influencia de la calidad del sueño, la nutrición y la hidratación en el rendimiento deportivo (Djaoui et al., 2017). Estos son elementos fundamentales que pueden ser gestionados y optimizados para mejorar la capacidad de un deportista para tolerar cargas más intensas y variables en el tiempo. La interacción de todos estos factores, tanto modificables como no modificables, crea un entorno complejo en el que se debe llevar a cabo una planificación y gestión cuidadosa con el fin de maximizar el rendimiento y el bienestar de la deportista (Figura 9).

Figura 9

Factores contextuales que influyen en la carga



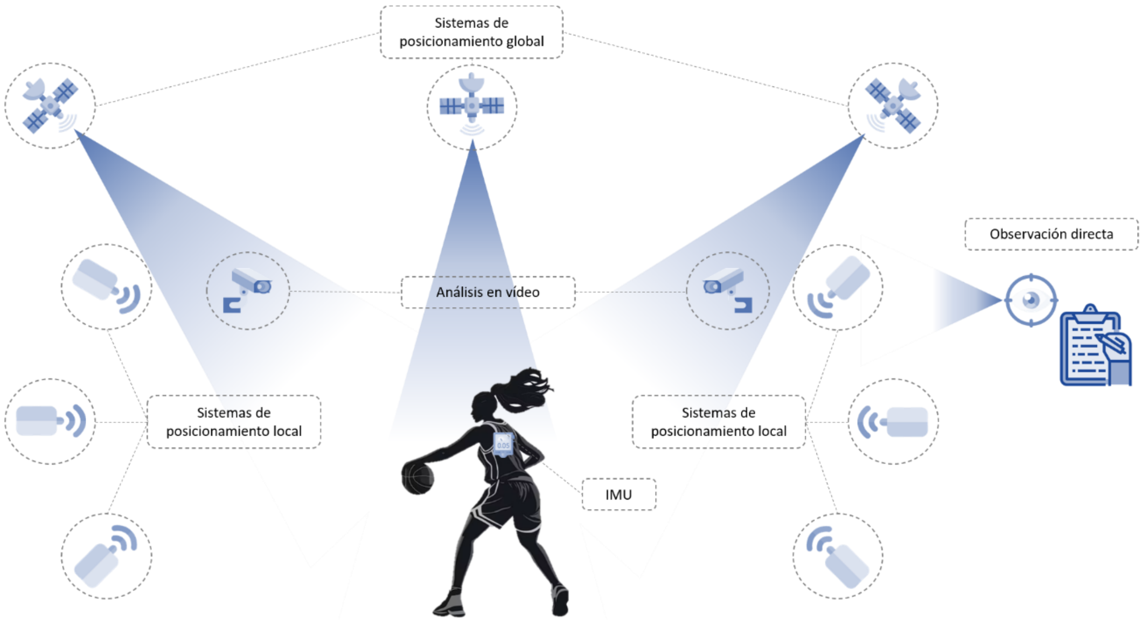
Nota. Los colores señalan cuánto de modificable es cada factor. En verde los elementos modificables, en amarillo los que podrían ser parcialmente modificables y en rojo los poco o nada modificables. Adaptado de *Contextual factors when managing athlete injury risk and readiness to perform*, de West et al., 2021.

2.4. Métodos para la monitorización de la demanda física

El estudio de la carga externa e interna requiere de una adecuada selección de los métodos y las variables en cada contexto (Figura 10 y Figura 11). Para ello, contemplar las características del deporte y los factores que determinan el rendimiento, colectiva e individualmente, en el corto y largo plazo, a la vez que se integran diferentes fuentes de datos es clave. Esto permitirá establecer valores de referencia y comprender la relación dosis-respuesta para una mejor toma de decisiones.

Figura 10

Métodos empleados en la monitorización de la carga interna



Observación directa

La mera observación del entrenamiento o la competición permite la cuantificación de parámetros de interés en la monitorización de la carga, como puede ser la duración y la densidad (Borresen & Ian Lambert, 2009). Aunque en los últimos años se han propuesto herramientas en la cuantificación de la carga en los deportes de equipo que tienen en cuenta parámetros específicos de las tareas, como puede ser el Sistema integral para el análisis de las tareas de entrenamiento (Ibañez et al., 2016) o la Escala de valoración de cargas técnico-tácticas (Coque, 2008, 2009). Ambos instrumentos de evaluación tratan de analizar los diferentes factores que configuran las tareas, categorizando sus elementos y otorgándoles una puntuación subjetiva (oposición, densidad, participantes, etc.). Herramientas de análisis que podemos complementar a través del análisis del ritmo de juego, ratio de acciones por unidad de tiempo (Seirul·lo Vargas, 2017). Las categorías y elementos de esta se resumen en la Tabla 3. Y, adicionalmente, se ha propuesto la percepción subjetiva (PS) del entrenador de la intensidad de la sesión y el estado de fatiga de sus deportistas o el conjunto del equipo durante el entrenamiento o competición (Foster, Heimann, et al., 2001). Un método que presenta algunos inconvenientes, motivo por el cual no se encuentra en la literatura de forma extensa.

Tabla 3

Diferencias entre Métodos Subjetivos de Observación Directa

EVCTT	**SIATE**
Escala: 1 a 4	Escala: 1 a 5
Grado de oposición	Grado de oposición
Densidad de la tarea	Densidad de la tarea
Número de ejecutantes	% Ejecutantes simultáneos
Carga competitiva	Carga Competitiva
Espacio	Espacio
Carga táctica	Implicación cognitiva

Nota. EVCTT: escala de valoración de cargas técnico-tácticas; SIATE: sistema integral para el análisis de las tareas de entrenamiento.

Análisis tiempo-movimiento a través del vídeo

Este es uno de los métodos más extendidos en la monitorización de la carga externa en los deportes de equipo al presentar pocas barreras de acceso y que se identifica como válido y específico en la literatura, y que no requiere de equipar al deportista con ningún dispositivo (Borresen & Ian Lambert, 2009; McInnes et al., 1995). Este se basa en la cuantificación, a través de la visualización en vídeo, el número de acciones ejecutadas, sean estas genéricas (caminar, correr, esprintar, saltar, etc.), o específicas del deporte (pases, lanzamientos a canasta, *dribbling*, bloqueos, etc.) (Ben Abdelkrim et al., 2010; Klusemann et al., 2012). Aunque al mismo tiempo presenta ciertas limitaciones e inconvenientes. Principalmente, su bajo ratio coste-beneficio al consumir una gran cantidad de tiempo y la necesidad de un nivel de entrenamiento previo de la persona encargada de la evaluación (Chambers et al., 2015). Además, se debe considerar la complejidad al discriminar, a través de imágenes, la intensidad de las acciones y replicar el criterio a lo largo del tiempo, como es el caso de correr o esprintar (Barris & Button, 2008). Estas limitaciones han motivado el desarrollo de software de análisis automatizados (STATS o *Second Spectrum*) (Sanguesa et al., 2017), permitiendo la cuantificación de acciones de forma más rápida incluso en tiempo real, y con un margen de error sistemático. A pesar de esto, parece que estos sistemas, parcial o totalmente automatizados, muestran diferentes niveles de validez cuando se evalúan diferentes acciones. En especial han mostrado una menor precisión y validez cuando las acciones se ejecutan a alta intensidad (Beato & Jamil, 2018). Esto podría ser un punto clave en la aplicación de estos métodos en el baloncesto, el cual es un deporte dominado por acciones de alta intensidad en espacios reducidos.

Sistemas de posicionamiento: de lo global a lo local

El uso de sistemas de posicionamiento debe su implementación al desarrollo de microsensores en los últimos años, los cuales detectan la posición de la deportista en un sistema de referencia, globales o locales (Coutts & Duffield, 2010).

En primer lugar, encontramos el Sistema Mundial de Navegación por Satélite o Sistema Mundial de Posicionamiento (GNSS o GPS, siglas en inglés), método empleado de forma mayoritaria en deportes de equipo al aire libre, debido principalmente a que obtienen su información a través del uso de satélites que orbitan alrededor de La Tierra (Hoppe et al., 2018). Un factor clave que los hace imprecisos en modalidades deportivas de interior al no poder recibir la señal de forma adecuada (Duffield et al., 2010). Este problema se ha solventado en los últimos años a través del empleo de Sistemas de Posicionamiento Local (LPS, siglas en inglés). Ambos presentan un funcionamiento similar, el emisor envía señales de forma constante y estas son captadas por los receptores. La diferencia temporal y espacial entre un registro y el siguiente permite conocer la direccionalidad e intensidad del desplazamiento de la deportista. Mientras que el GNSS o GPS usa como referencia el globo terráqueo, el sistema de LPS emplea antenas posicionadas alrededor del terreno de juego y tecnología de radiofrecuencia, mostrando un margen de error menor debido a: 1) mayores tasas de muestreo; 2) menor distancia entre emisor y receptor; 3) menos interferencias en la señal (Fontana, 2004). Aunque también presenta sus limitaciones, siendo el número de antenas un aspecto clave en la precisión de los datos (Bastida-Castillo et al., 2019), algo que ocurre también en el sistema GNSS/GPS (Scott et al., 2016).

Las métricas que estos sistemas nos reportan se basan, como se ha señalado anteriormente, en la posición y en el tiempo. De esta manera se puede estudiar el volumen, a través de la distancia total recorrida, y la intensidad, evaluando la velocidad o las aceleraciones. Adicionalmente, y en especial en los últimos años, estos sistemas se emplean para identificar las relaciones espacio-temporales entre deportistas y entre estos y la pelota, permitiendo investigar otras variables como la distancia con la pelota, el área ocupada por cada jugadora o la sincronía entre estos (Mateus et al., 2019), lo que podría ser de gran interés para el análisis táctico.

Unidades de medición inercial

Recientemente se han incorporado al estudio de las demandas físicas de los deportes de equipo las IMU (Montgomery & Maloney, 2018). Estos son pequeños dispositivos que aglutinan un conjunto de microsensores, entre los que se destacan el acelerómetro, el giroscopio y el magnetómetro, reportando los cambios en los diferentes ejes de movimiento. Sus ventajas principales radican en que es el propio deportista quien lo equipa, desapareciendo así las interferencias en las señales que se identifican en los sistemas de posicionamiento. Además, cuentan con mayores frecuencias de muestreo, y por tanto mayor sensibilidad a los pequeños cambios (Boyd et al., 2011, 2013). Siendo necesario tener presente que estos corresponden a los segmentos corporales en los que se ubican (comúnmente la zona alta de la espalda). Ahora bien, a pesar de sus ventajas respecto a otras tecnologías, cuentan con sus propias limitaciones. La más importante es que no se puede asegurar que todos los sensores midan con el mismo nivel de precisión, por lo que se recomienda que los deportistas utilicen siempre la misma unidad de registro (Nicolella et al., 2018). Además, estas señales son tratadas de diversas formas por cada uno de los fabricantes, siendo en muchos casos procesos opacos y sujetos a las actualizaciones, de *firmware* y *software*. Estos hechos podrían hacernos pensar que es necesario reflexionar sobre la posible necesidad constante de calibrar y validar constantemente estos sensores (J. L. Fox et al., 2019; Muyor et al., 2018; Nicolella et al., 2018).

De entre todos los sensores, el más utilizado es el acelerómetro. Sus datos se emplean principalmente para establecer umbrales de aceleración, positivos y negativos, para cuantificar las acciones de alta intensidad y así describir la exigencia neuromuscular (Petway et al., 2020). Además, de la combinación de los datos de cada uno de sus ejes se calcula el movimiento global, identificando esta métrica identificada como *Player Load*© (PL), una variable vectorial dependiente del tiempo. Y adicionalmente se emplean otras métricas como los saltos o impactos (Arcos et al., 2013; Schelling & Torres, 2016).

$$Player\ Load = \frac{\sqrt{\left(a_{y1} - a_{y-1}\right)^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}}{100}$$

Recientemente, en base a estas métricas reportadas por los IMU se han propuesto los escenarios de máxima exigencia en el evento, análisis basados en técnicas de promedios móviles aplicadas sobre las señales monitorizadas (Fernández et al., 2020; Vázquez-Guerrero et al., 2020). García Garrido (2021), en su tesis doctoral, resalta la importancia de analizar, sobre cualquiera de las métricas registradas, los períodos en los que el deportista soporta las demandas más altas, pudiendo utilizar diferentes lapsos de tiempo (10, 20, 30, 60 segundos, etc.).

2.5. Métodos para la monitorización de la respuesta fisiológica

Figura 11

Métodos empleados en la monitorización de la carga interna

2.2.1. Percepción subjetiva del esfuerzo

Los métodos subjetivos, por su sencillez en la implementación, bajo coste y ser un método no invasivo son ampliamente utilizados en los deportes de equipo (Halson, 2014). Estos persiguen el objetivo de cuantificar la sensación individual de la deportista tras un esfuerzo físico, evaluando la exigencia física, la fatiga o el malestar (Faulkner & Eston, 2008). Además, se han demostrado como métodos válidos y fiables al guardar estos una relación con otros parámetros fisiológicos (FC media, VO_2, lactato en sangre – BLC, siglas en inglés –, etc.) y de rendimiento (variables de intensidad y volumen) (Chen et al., 2002; Haile et al., 2016). Pero se debe resaltar que su resultado es dependiente de complejas interacciones fisiológicas (niveles hormonales, presencia y concentración de neurotransmisores, glucógeno muscular y sanguíneo, ventilación pulmonar, condiciones ambientales, estado psicológico y emocional, rasgos de personalidad, etc.), un aspecto clave para su adecuada implementación e interpretación (Halson, 2014).

De forma resumida, la PS del esfuerzo (RPE, siglas en inglés) ante la carga de entrenamiento fue estudiada inicialmente como "la sensación de como de duro o extenuante es una tarea física" y evaluada en una escala de 6-20 (G. Borg, 1970). Con el tiempo se han implementado otras preguntas y rangos de puntuación (E. Borg & Borg, 2002), aunque en los deportes de equipo la propuesta de Carl Foster es la más extendida. Un valor entre 1-10 que evalúa cuánto de dura físicamente ha sido una sesión (Foster, Florhaug, et al., 2001). Pero existen otras aproximaciones de interés, como la de Marcora, quien emplea tres constructos separados al percibir el esfuerzo: sensación consciente de cómo de duro ha sido, dureza y lo estresante que es físicamente una tarea (Marcora, 2009). Cada uno de ellos se propone evaluar de forma independiente y en tres categorías, para las extremidades/músculos implicados, el impacto cardiovascular y la sensación general de esfuerzo.

A pesar de su facilidad y sencillez, es necesario remarcar algunos aspectos metodológicos importantes (sesgos del evaluado, sus pares y el evaluador, el tiempo transcurrido desde la actividad, etc.), la variedad de propuestas presentes la literatura (escalas, instrucciones, etc.) (Halperin & Emanuel, 2020) y los debates sobre la taxonomía, como el caso de los términos *effort* y *exertion*, la cantidad de energía física o mental que requiere una tarea y la sensación de dureza y estrés de la tarea respectivamente (Abbiss et al., 2015).

Adicionalmente, algunos autores proponen calcular nuevas métricas empleando estos datos. Entre estos, el más presente en la literatura científica en los deportes de equipo es la RPE de la sesión. Obteniendo esta de la multiplicación de los minutos de exposición por el valor reportado en la escala (Foster, Florhaug, et al., 2001). Una propuesta que trata de incorporar al estudio de la carga un valor de volumen de entrenamiento.

2.2.2. Otros cuestionarios subjetivos

Previamente se ha resaltado la importancia del estado emocional y psicológico como un factor que impacta en el constructo de carga interna. Este es uno de los motivos por los que algunos autores han implementado cuestionarios subjetivos en el ámbito deportivo, recabando así información sobre el bienestar general (Hooper et al., 1995), estado de ánimo (Main & Grove, 2009), calidad del sueño y percepción de la recuperación (Kellmann & Kallus, 2001), estrés (Rushall, 1990), demandas de la vida diaria (Rushall, 1990), relación entre rendimiento y vida cotidiana (Ruiz et al., 2017), etc. Y, del mismo modo que ocurre con el método de RPE, estos son fáciles de implementar, así como válidos y fiables. Aunque por contra, estos métodos requieren de una mayor familiarización, guía y educación de la deportista, así como una relación de sinceridad para una precisión en el análisis, percibiéndose en ocasiones como un método invasivo. La tabla 4 resume las características de algunos de los métodos subjetivos más empleados en los deportes de equipo.

Tabla 4

Métodos, Categorías, Preguntas y Escalas de los Métodos Subjetivos utilizados en los Deportes de Equipo

Método	Categorías	Escala
Test bienestar general	Fatiga, cansancio muscular, calidad del sueño, estrés y estado de ánimo	5 preguntas 1 (muy mal) - 5 (muy bien)
Test de Hooper	Estrés, fatiga, sueño y cansancio muscular	4 preguntas 1 (muy bien) - 7 (muy mal)
POMS	Tensión-ansiedad, depresión, ira-hostilidad, vigor-actividad, fatiga y confusión-desconcierto	65 preguntas. 0 (bien) - 4 (mal)
Rest-Q	Estrés (7 subcategorías) y recuperación (5 subcategorías)	12 preguntas (muy mal) 0 a 6 (muy bien)
DALDA	Estrés y síntomas del estrés	25 preguntas Respuesta negativa, normal o positiva
IZOF	Preguntas agradables y desagradables	28 preguntas 1 – 11

Nota. Perfil del estado de ánimo (siglas en inglés); Rest-Q: Cuestionario de descanso (siglas en inglés); DALDA: Análisis diario de las exigencias vitales de los deportistas (siglas en inglés); Zona individual de funcionamiento óptimo (siglas en inglés).

2.2.2. Monitorización de la actividad cardíaca

Empleada en multitud de poblaciones, condiciones y situaciones, la monitorización de la actividad cardíaca es uno de los métodos más empleados en la cuantificación de la carga interna en los deportes de equipo (Vanrenterghem et al., 2017). Debido principalmente a su fiabilidad y precisión, tener un precio reducido, ser un método eficiente con el tiempo de análisis, la posibilidad de análisis en tiempo real, etc. (Cardinale & Varley, 2017).

La métrica más estudiada en la monitorización del corazón durante el esfuerzo físico es la FC, expresando en pulsaciones por minuto valores mínimos, promedio y máximos durante la actividad física (Borresen & Ian Lambert, 2009). En los últimos años se ha destacado, como un método en la evaluación del estado del sistema nervioso autónomo la variabilidad de la frecuencia cardíaca. Este permite evaluar la relación entre actividad nerviosa, el estado físico, la respuesta a la carga y la propia predisposición al entrenamiento (Aubert et al., 2003).

A pesar de su extenso uso, este no es un método libre de limitaciones, ya que en ocasiones muestra resultados contradictorios, inconsistencias metodológicas en su uso o malinterpretaciones de los resultados. Para comprender esta afirmación se debe resaltar que la FC es un reflejo de la actividad simpática y parasimpática del sistema nervioso, condicionada por factores ambientales (el ruido, la luz, la temperatura, la presión atmosférica), patológicos (insuficiencias cardiovasculares), psicológicos y emocionales (estado de ánimo, emociones, estrés), no modificables (sexo, edad), de estilo de vida (ejercicio físico, sueño, medicación, consumo de tabaco y alcohol) o por la propia actividad física realizada (intensidad, duración, densidad) (Schneider et al., 2018). A todo ello debemos sumar la idea de que la respuesta cardíaca no es inmediata. Existe un retardo entre la actividad muscular y la variación de la FC, subordinada a la intensidad y duración del esfuerzo para proveer los sustratos metabólicos necesarios (López Chicharro & Fernández Vaquero, 2008).

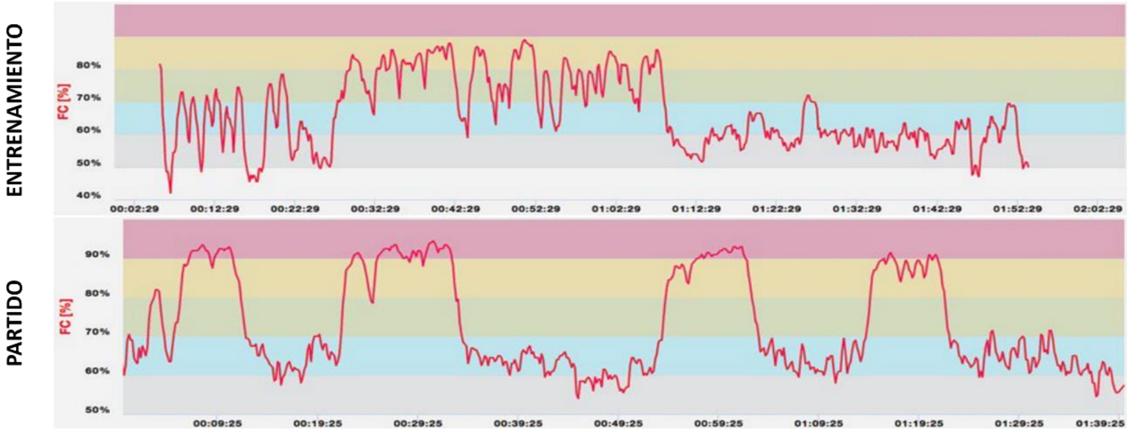
Para su uso adecuado, el momento de monitorización de la FC es clave. En la literatura se han identificado tres momentos: en situación de reposo (sentado o decúbito supino durante 5-10 minutos), durante el ejercicio (a través de tareas estandarizadas en tiempo e intensidad) y posterior a la finalización del ejercicio (evaluación de los reajustes hemodinámicos, el estado de forma, de bienestar y la disposición para rendir nuevamente) (Buchheit, 2014). Dependiendo de cada uno de estos las métricas de interés varían. De forma resumida, la evaluación en una situación de reposo permite identificar adaptaciones crónicas, mientras que la observación durante la actividad e inmediatamente posterior nos permiten evaluar la respuesta aguda al ejercicio, y evaluar la capacidad del organismo de reequilibrar la homeostasis. Recordemos los posibles escenarios detallados en la Figura 8.

Adicionalmente, a través del uso de la FC, algunos autores han propuesto el cálculo de diferentes índices. Este es el caso de los impulsos del entrenamiento de Banister ($TRIMP_B$) (Banister, 1991), los TRIMP de Lucia (Lucía et al., 2003) o el método de Edwards, conocido como el sumatorio de zonas de frecuencia cardíaca ponderadas (SHRZ, siglas en inglés) (Edwards, 1993). Este último es el que más se ha utilizado en los deportes de equipo (Bartlett et al., 2017; Vanrenterghem et al., 2017) y se basa en contabilizar el tiempo que el corazón trabaja en cada zona de pulsaciones (originalmente cinco zonas – Figura 12 – respecto a la FC máxima: Zona 1: 50-60%; Zona 2: 61-70%; Zona 3: 71-80%; Zona 4: 81-90%; Zona 5: 91-100%) y ponderar el tiempo en cada una de estas por una constante. La suma de cada una de las multiplicaciones será el valor de carga de la sesión, siendo este un valor de referencia individual expresado en unidades aleatorias.

$$SHRZ = Zone\ 1 * 1 + Zone\ 2 * 2 + Zone\ 3 * 3 + Zone\ 4 * 4 + Zone\ 5 * 5$$

Figura 12

Representación de la actividad cardíaca en el entrenamiento y la competición en jugadoras de baloncesto



Nota. En colores se representan las diferentes zonas de actividad cardíaca (zona 1: gris, zona 2: azul, zona 3: verde, zona 4: amarillo, zona 5: rojo).

2.2.3. Parámetros ventilatorios

En los deportes de equipo, la monitorización directa de la función respiratoria presenta grandes retos, en especial por la sofisticación del material y la necesidad de equipar al deportista con dispositivos voluminosos que interfieren en el campo de visión (máscara y tubo) y el rango de movimiento (chaleco y dispositivo en la zona alta de la espalda). Además de aumentar el riesgo de sufrir daño o estropear el dispositivo debido a los impactos (Cardinale & Varley, 2017). Pero estos inconvenientes no han impedido que encontramos en la literatura científica publicaciones que han equipado a deportistas durante la práctica en los deportes de equipo (Narazaki et al., 2009), estudiando principalmente el VO_2, al ser esta métrica un indicador de la condición aeróbica en los deportes de equipo (Osgnach et al., 2016). Debido a que conocemos que el VO_2 mantiene una relación lineal con la intensidad del esfuerzo y los valores de FC, muchos autores han estudiado el VO_2 a través de cálculos indirectos (Esposito et al., 2004).

2.2.4. Biomarcadores en fluidos corporales

El análisis de la respuesta fisiológica se ha basado durante muchos años el estudio de los fluidos corporales, destacando en ellos los biomarcadores obtenidos en sangre venosa y capilar, el sudor, la orina o la saliva (Calleja-González & Terrados, 2009). Entre estos, los biomarcadores sanguíneos han sido los más utilizados en la monitorización de la carga interna (Bourdon et al., 2017), aunque requieren de punzar al deportista, así como otros factores procedimentales (higiene, tratamiento de las muestras, etc.) (Calleja-González & Terrados, 2009). Destacan dos por encima del resto. El primero, y más extendido, es el análisis de la BLC. Y en especial el pico máximo de concentración. El cual se ha empleado como un indicador de la contribución energética de las vías anaeróbicas (Matthew & Delextrat, 2009; Scanlan et al., 2012), a pesar de que se recomienda comprender la fisiología de los procesos glucolíticos y oxidativos para conocer las limitaciones de estos métodos (lactato *vs* ácido láctico, procesos de reciclaje, acumulación de piruvato, etc.) (Calleja González et al., 2008). En segundo lugar, entre los biomarcadores en sangre se han propuesto son los niveles de creatina quinasa (CK, siglas en inglés) al ser este un indicador de daño muscular, relacionado por tanto con las demandas físicas (Young et al., 2012), la percepción del esfuerzo (Conte et al., 2023) y los procesos de recuperación (Ascensão et al., 2008).

Estos dos biomarcadores aportan información relativa a la respuesta más inmediata, pero existen otros que permiten conocer cómo el organismo responde a la carga crónica, como es el caso de los marcadores en saliva, destacando el estudio de los niveles absolutos de testosterona, cortisol, la relación entre ambas hormonas, inmunoglobulina A y el total de proteínas presentes (Moreira et al., 2012; Schelling et al., 2015). El estudio de estos parámetros ha mostrado fluctuaciones a lo largo de los diferentes períodos del año, aumentando los valores de cortisol a medida que avanza la temporada (Kamarauskas & Conte, 2022). Y, por último, aunque con menor volumen de evidencia que los respalde, también se ha propuesto el análisis de metabolitos en orina (Daskalaki et al., 2015) y sudor (Baker et al., 2022) en la monitorización de la carga interna, analizando las concentraciones de urea y minerales respectivamente

Aunque estos métodos generan un gran interés, es conveniente resaltar la dependencia de estos biomarcadores con muchos procesos fisiológicos que se producen de forma simultánea, por lo que algunos autores recomiendan no caer en el reduccionismo al emplear estos en los procesos de monitorización de la carga (Cardinale & Varley, 2017).

CAPÍTULO 2

OBJETIVOS E HIPÓTESIS

El objetivo principal de esta tesis doctoral es estudiar los métodos y métricas existentes para la monitorización de la carga en el entrenamiento y la competición en el baloncesto femenino, incluyendo la evaluación de los valores reportados a través de estos métodos en los diferentes niveles competitivos. Además de determinar la calidad metodológica de la evidencia científica disponible. Por otro lado, se pretende monitorizar los valores de carga en el entrenamiento y la competición y describir la relación entre la demanda física y la respuesta fisiológica en la jugadora de baloncesto.

Los objetivos e hipótesis específicas de cada estudio fueron:

1. Identificar y analizar los métodos, métricas y valores de referencia en la monitorización de la demanda física en el entrenamiento y la competición en el baloncesto femenino presentes en la literatura disponible (Publicación I).
   - Se hipotetizó que, en comparación con los métodos empleados en otros deportes de equipo, y en especial el baloncesto masculino, el baloncesto femenino cuenta con menos evidencia científica, así como del uso de métodos y variables diferentes.
2. Reconocer y describir los métodos, métricas y valores de referencia en la monitorización de la respuesta fisiológica en el entrenamiento y la competición en el baloncesto femenino presentes en la literatura disponible (Publicación II).
   - Se hipotetizó que el estudio de la respuesta fisiológica en el baloncesto femenino se basa en el registro y reporte de valores de frecuencia cardíaca y métodos subjetivos, con poca evidencia sobre otros parámetros fisiológicos.
3. Describir los valores y la relación de la demanda física y la respuesta fisiológica en jugadoras de baloncesto durante el entrenamiento (Publicación III).
   - Se hipotetizó que la relación que guardan ambos constructos de la carga es particular de cada contexto. Esto nos hace descartar valores de referencia de otras poblaciones e incluso de equipos con características similares. Es necesario una evaluación y seguimiento específico de cada contexto.
4. Monitorizar las demandas físicas de la competición en jugadoras de baloncesto y estudiar la relación con los parámetros de la estadística del baloncesto durante la temporada regular (Publicación IV).
   - Se hipotetizó que los valores de carga se ven alterados en relación a la posición de la jugadora, las interrupciones y ritmo del juego, el número de acciones en las que participa y su implicación en las acciones de éxito

CAPÍTULO 3

MATERIALES Y MÉTODOS

Esta tesis doctoral se compone de un total de cuatro estudios científicos, los cuales persiguen conseguir los objetivos descritos en el apartado anterior haciendo uso de diferentes metodologías de investigación.

Primeramente, se resumirá y examinará la evidencia científica disponible a través de la realización de revisiones sistemáticas, tanto en relación a la demanda física como a la respuesta fisiológica. Estos dos trabajos persiguen el fin último de proporcionar una visión integral de las herramientas disponibles y su aplicación en el contexto específico del baloncesto femenino. Ambas se presentan sin meta-análisis, debido esto a la gran heterogeneidad de los datos que más adelante se expondrá. En segundo lugar, se llevarán a cabo estudios descriptivos longitudinales en los que se monitorizarán los eventos de entrenamiento y competición durante la liga regular y estudiando la relación entre la carga externa e interna.

En los estudios originales de naturaleza descriptiva y longitudinal los lectores encontrarán que el primero de ellos analiza la carga en el entrenamiento y la relación entre la demanda y la respuesta en jugadoras jóvenes. Por otro lado, el último de los estudios de esta tesis doctoral investiga la demanda física en jugadoras adultas durante la competición a lo largo de la temporada regular. A diferencia del resto de los estudios, este no ha sido publicado en ninguna revista en el momento de presentación de esta tesis doctoral.

En las secciones siguientes se presentan los manuscritos publicados y el protocolo de investigación correspondientes. Los lectores observarán que no se ordenan de forma cronológica las publicaciones. Una decisión adoptada con tal de facilitar la aproximación y comprensión de la temática.

Para obtener información más detallada, se remite a los lectores a la sección de métodos específicos de cada publicación

CAPÍTULO 4

PUBLICACIONES

Publicación I

External Load Monitoring in Female Basketball: A Systematic Review

Espasa-Labrador, J., Calleja-González, J., Montalvo, A. M., & Fort-Vanmeerhaeghe, A. (2023). External Load Monitoring in Female Basketball: A Systematic Review. *Journal of human kinetics*, *87*, 173–198. https://doi.org/10.5114/jhk/166881.

Journal of Human Kinetics volume 88/2023, 173–198 DOI: 10.5114/jhk/166881

Section III – Sports and Physical Activity

External Load Monitoring in Female Basketball: A Systematic Review

by

Javier Espasa-Labrador [1], Julio Calleja-González [2,3], Alicia M. Montalvo [4], Azahara Fort-Vanmeerhaeghe [5,6,]*

The primary aim of this systematic review was to summarize the current state of research in relation to external load monitoring in female basketball. The review was conducted according to the PRISMA-P® statement. Publications included in the review: 1) were original research, 2) evaluated healthy female basketball players, and 3) monitored basketball practice and competition. The STROBE scale was used to assess quality. A total of 40 publications were included. The external load was assessed during practice (n = 9), competition (n = 11) or both events (n = 8). Also, time-motion analysis was implemented in practice (n = 2), competition (n = 9), or both events (n = 1). Accelerometry (n = 28) and time-motion (n = 12) analysis were the most frequently used methods. However, a wide range in methods and variables were used to quantify the external load. Placement of devices on the upper back and measuring with a sampling frequency of 100 Hz were most common. Player Load (PL) values increased with the competitive level of players and were higher in competition compared to training. Small-sided games can be used to gradually increase loads in female basketball (PL 5v5: 34.8 ± 8, PL 3v3: 47.6 ± 7.4, TD 5v5: 209.2 ± 35.8 m, and TD 3v3: 249.3 ± 2.8 m). Tasks without defense seemed to be less demanding. More research is needed to reach a consensus on load control in women's basketball, on what data are important to collect, and how to use and transfer knowledge to stakeholders.

***Keywords**: physical demand; dose training; team sports; woman athlete*

Introduction

Basketball is one of the most popular sports in the world. Its popularity has led to interest in advancing scientific knowledge of the sport, especially with the development of new technology over the last few decades (Schelling and Torres-Ronda, 2013). Baskebtball consists of aerobic and anaerobic activity during a variety of actions, such as acceleration and deceleration, change of direction, jumping or physical contact. This activity is also referred in literature as an external load (Petway et al., 2020). The external load occurs simultaneously with situations that require an understanding of the game, continuous decision-making, and anticipation of the opponents' actions (Fox et al., 2017).

The load has two constructs: an external load and an internal load. The former refers to a dose and the latter to a response (Espasa-Labrador et al., 2021). There are three main methods used in the literature to monitor the external load: 1) video analysis, 2) positioning analysis (global and local positioning systems, GPS and LPS, respectively), and 3) accelerometry (combined with other sensors, such as magnetometer or gyroscope) (Fox et al., 2017). Most of this growing interest in the use of wearable devices to quantify the external load is

[1] *INEFC-Barcelona Research Group on Sport Sciences (GRCE), National Institute of Physical Education of Catalonia (INEFC), University of Barcelona, Barcelona (UB), Spain.*
[2] *Department of Physical Education and Sport, Faculty of Education and Sport, University of the Basque Country, Vitoria, Spain.*
[3] *Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia.*
[4] *College of Health Solutions, Arizona State University, Phoenix, AZ, USA.*
[5] *FPCEE and FCS Blanquerna, SAFE research group, Ramon Llull University, Barcelona, Spain.*
[6] *Segle XXI Female Basketball Team, Catalan Federation of Basketball, Esplugues de Llobregat, Spain.*
* Correspondence: azaharafv@blanquerna.url.edu

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focused on the latter two methods mentioned (Petway et al., 2020). Wearable devices can be used to gain an understanding of how intense an effort has been for each individual player. This allows for the evaluation of intensity and volume during a basketball game and evaluation of players' fitness. The use of this technology has allowed sports scientists to gain a better understanding of the "dose" of activity (Petway et al., 2020). In turn, the information gained may contribute to training decisions (Vazquez-Guerrero et al., 2020), such as how to structure training plans and routines, and how to target training towards specific sport tasks. External load data can be used in combination with internal load data to understand how players adapt to training at specific points in the season (McLaren et al., 2018). While the internal load is individual and cannot be modified, the external load provides coaches with a tool to promote appropriate physiological adaptations. To achieve this goal, it is essential to determine the reference values of the external load in female basketball. By establishing reference values, coaches can accurately assess the physical demands placed on their players and tailor their training programs accordingly.

In this sense, we found systematic review publications that summarized external loading methods and physical demands values in male and female basketball players (Reina et al., 2020a; Russell et al., 2020; Stojanović et al., 2018). The above publications discussed the devices utilized, the metrics, and their limitations. Furthermore, the analyses were predominantly based on studies conducted on male players, either due to a larger sample size or an exclusive examination of only one event. Therefore, it is crucial to identify and examine the final outcome reported in publications and also consider the studied populations, which will enable us to determine the specific physical demands imposed on female basketball players during both practice and competition.

The aims of this systematic review were to summarize and compare the external load values obtained in female basketball players across different competitive age, levels, and events, during practice and competition.

Methods

This systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA-P) guidelines (Moher et al., 2016).

Eligibility Criteria

Studies were eligible for inclusion when they met the following criteria: 1) peer-reviewed original research articles; 2) populations were healthy female basketball players of any age or level of competition; 3) research described the external load during basketball practice or competition in any format (5 versus 5 or 3 versus 3). There were no filters applied by language in order to identify all possible publications. Exclusion criteria were: 1) post-event assessment of biomechanical or neuromuscular variables; 2) validation of research instruments; 3) performance assessment; 4) wheelchair basketball studies; 5) studies that were performed for clinical purposes or therapeutic use.

Information Sources

The search was carried out in four international databases: EBSCO, PubMed, Scopus, and Web of Science (WOS). The search was conducted through April 30, 2023.

Search Strategy

The following search equation was used to find the relevant articles: *("female" OR "woman") AND "basketball" AND ("monitoring" OR "training" OR "external" OR "physical") AND "load"*. Furthermore, the reference sections of all relevant articles were also examined, applying snowball strategy (Linder et al., 2015).

Study Records

The search for potential publications was independently performed by two different authors (J.E.-L. and J.C.-G.). Articles were cross-referenced to identify duplicates prior to starting the screening process. An initial screening of the titles and abstracts was performed to check the eligibility criteria. When a paper could not be rejected with certainty, it was included in the eligible papers for full-text evaluation. The articles were then assessed for eligibility through a full-text screening, and those meeting the established criteria were included in the systematic review. The number of studies meeting the pre-specified inclusion criteria, and those excluded and the reasons for their exclusion were recorded and codified. All disagreements at each level were resolved by the third reviewer (A.F.-V.).

Data Extraction

Once articles were selected for inclusion, the following data were extracted: 1) study source (author/s and year of publication); 2) type of event studied (practice or competition); 3) population of the sample, including the number or participants, mean age and the competitive level (elite, professional, amateur and youth players); 4) unit of observation (individual, team, etc.); 5) methods and devices utilized for quantification of the load (identifying manufacturer); 6) variables identified for each method; 7) outcomes reported for each variable. For time-motion analysis, additional data were extracted, including the type of motion categorized or specific actions. In those publications in which the variables to be extracted were not shown, information was requested from the corresponding author via e-mail.

The study participants were categorized into several groups: elite, professional, semi-professional, amateur and youth players. The elite group was defined by participants in the Women's Basketball Association (WNBA), National Collegiate Athletic Association (NCAA) Division I, Euro League Women and International Basketball Association (FIBA). Professional was defined as athletes in the first and second divisions in any continent who were over 19 years old (Petway et al., 2020). The amateur level was defined as under the professional level previously mentioned. Lastly, youth competition was defined as a population that was 19 years of age or younger. Studies that analysed practice or competition through video analysis were categorized as "time-motion analysis". Friendly games were analysed jointly with competition events while simulated games during training were included as practice events.

Final outcomes of the interventions were extracted independently by two authors (J.E.-L. and J.C.-G.) using a spreadsheet (Microsoft Excel, Microsoft Inc., Seattle, WA, USA). Subsequently, disagreements were resolved through discussion until a consensus was reached or third-party adjudication (A.F.-V.). Furthermore, the nomenclature of each original article was homogenised for better analysis of the data.

Quality Assessment and Risk of Bias

The quality of all included studies was assessed following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies (Von Elm et al., 2007). The following scale was used to classify the study quality: 1) good quality (>14 points, low risk of major or minor bias); 2) fair quality (7–14 points, moderate risk of major bias); and 3) poor quality (<7 points, high risk of major bias). The total STROBE score was obtained through an evaluation of the 22 items of the STROBE checklist. For enhanced scientific rigour, potential study limitations were independently assessed for methodological quality and risk of bias by two authors (J.E.-L. and J.C.-G.), with any disagreements resolved by third-party evaluation (A.F.-V.).

Results

Study Selection

A total of 515 articles were identified in the initial search. Of the 515 articles, 299 were duplicates, resulting in a total of 216 unique articles for the title and abstract review. A total of 176 articles were removed following the title and abstract screening, leaving 40 articles to be included in the full-text assessment for eligibility. Following full-text assessment, nine articles were excluded for the following reasons: participants did not match inclusion criteria (n = 1, male players); and outcomes did not match inclusion criteria (n = 6, internal load monitoring; n = 2, performance assessment). Consequently, 31 articles met the previously defined inclusion criteria and were considered in this final systematic review. Upon completion of the snowball search strategy (Linder et al., 2015), nine more articles were included, totalling 40 articles. Figure 1 details all processes and results obtained by search strategy. A large variation was observed in variables investigated across included studies. As a result, studies were clustered by the type of the event. All results are included and summarised in tables (1–5).

Study Participants

Samples and their characteristics are presented in Table 1. With regard to populations, youth players were monitored in 13 publications, while the remaining studies monitored adults and were categorized into adult amateur (six publications), professional (12 publications) and elite (14 publications) players (Table 1).

In the 40 included studies, there were identified two categories of load monitoring techniques: 1) wearable devices, and 2) video analysis. Of the studies included, 20 articles reported the external load during practice and 29 reported the external load during competition. Of those, nine reported external load data for both practice and competition. Studies that monitored practice sessions investigated different tasks. Tasks were categorized as follows: 1) without defense, 2) superiority task, 3) small sided game, 4) field-court session, and 5) simulated game during practice. Seven other studies investigating practice did not specify the tasks analysed. For competition, 26 studies reported external load data during a 5*v*5 format, while three studies reported external load data during a 3*v*3 format. Among those studies that investigated a 5*v*5 format, only one was a friendly match, while the rest were official competition.

Outcome Variables

The clusters were external load monitoring through wearable devices during practice (Table 2) and competition (Table 3). Some studies described external load data through positioning systems such as GPS or LPS. Those publications collected different outcomes, identifying distance covered by players and how much of this distance was covered at high speed. Finally, one study showed how many sprints were detected during the event.

Of the articles that utilized accelerometers during practice, 14 publications used Player Load (PL) to evaluate the global physical demands, eight articles used absolute PL values, and six presented values of PL relative to time. Six publications used PL absolute and six PL relative to time values during competition. Some publications presented calculations of some indices, such as monotony and strain, through PL. Other publications studied total movement by equipping players with wrist accelerometers, showing values as the sum of movement detected, and expressing values in time spent in different intensity zones. Finally, some articles included global movement assessment inertial movement analysis (IMA) across accelerometry. Six articles were identified that provided data about total accelerations and decelerations detected during an event. Four of them presented values of the number of accelerations and decelerations related to time and one more showed calculation of a ratio between both types of actions. Moreover, other studies categorized accelerations and decelerations during different types of actions, such as jumps, steps, impacts, and changes of direction, and presented absolute values or values relative to time. Finally, some studies presented outcomes related to accelerometry, such as duration of accelerations, and peak acceleration.

Lastly, articles using time-motion analysis presented varying common actions during practice or competition including: 1) standing or walking, 2) jogging, 3) running, 4) sprinting, and 5) jumping. Some of the articles included clustered previous outcomes in three categories: 1) low-intensity shuffle, 2) medium-intensity shuffle, and 3) high-intensity shuffle. Also, three investigations described values of specific technical actions of basketball, such as dribbling or passing. All of these were summarized in Tables 4 and 5.

Quality Assessment and Risk of Bias

Table 1 details the quality assessment score of each study via the STROBE tool. Studies were categorized as of good (n = 29), fair (n = 11) or poor quality (n = 0). Among the main problems in the assessment of the study quality, it was noted that: 1) ten studies adequately described the design, 2) two studies assessed bias, 3) one publication adequately detailed the sample size, and 4) two publications adequately reported changes in participants. The 11 studies labeled as of fair quality did not adequately report some aspects, i.e., a) study design, b) study limitations, c) generalization of results, and d) sources of funding. In addition, there were generally few studies that evaluated potential bias (n = 1) and sample size (n = 1).

Table 1a. Basic characteristics and quality assessment of studies included in this systematic review.

Publication	n	Level	Age (years)	Event	Load monitoring	Study quality (points)
Matthew and Delextrat, 2009	9	A	25.8 ± 2.5	G	IL; TM	Fair (14)
Narazaki et al., 2009	6	E	20.0 ± 1.3	P	IL; TM	Fair (14)
Delextrat and Calleja-González, 2012	9	Pro	24.3 ± 4.1	P; G	IL; TM	Fair (14)
Klusemann et al., 2012	8	Y	17.4 ± 0.7	P	IL; TM	Good (16)
Scanlan et al., 2012	12	A	22.0 ± 3.7	G	IL; TM	Good (15)
Oliveira-Da-Silva et al., 2013	96	E	27.8 ± 4.4	G	TM	Fair (13)
Conte et al., 2015	6	E	27 ± 4	G	TM	Good (17)
Delextrat et al., 2015	42	Pro	25.9 ± 4.3	G	TM	Fair (13)
Scanlan et al., 2015	12	Pro	22.0 ± 3.7	G	TM	Good (17)
Herran et al., 2017	10	Y	15.0 ± 1.0	P	EL	Fair (14)
Peterson and Quiggle, 2017	5	E	20.0 ± 1.0	P; G	EL	Good (15)
Reina et al., 2017	10	A	21.7 ± 3.7	P; G	EL; IL	Fair (13)
Staunton et al., 2018a	10	Pro	27.0 ± 5.0	G	EL	Fair (14)
Staunton et al., 2018b	9	Pro	27.0 ± 5.0	P	EL	Fair (13)
Montgomery and Maloney, 2018	208	E; Y	22.9 ± 5.6	G	EL; IL	Good (16)
Ransdell et al., 2019	6	E	19.7 ± 1.5	G	EL	Good (15)
Reina et al., 2019a	48	Y	U18	G	EL	Fair (14)
Coyne et al., 2019	12	E	27.8 ± 3.6	P	EL; IL	Good (17)
Reina et al., 2019b	10	A	21.7 ± 3.7	P; G	EL; IL	Good (18)
Reina et al., 2019c	10	A	>18	P	EL; IL	Fair (14)

NR: not reported; A: amateur; E: elite; EL: external load; G: game; IL: internal load; P: practice; Pro: professional; TM: time-motion analysis; Y: youth

Table 1b. Basic characteristics and quality assessment of studies included in this systematic review. Continued.

Publication	n	Level	Age (years)	Event	Load monitoring	Study quality (points)
Reina et al., 2019d	12	Y	U13	P; G	EL; IL	Good (15)
Portes et al., 2020	48	Y	17.0 ± 1.0	G	EL	Good (16)
Reina et al., 2020b	48	Y	U18	G	EL	Good (15)
Reina et al., 2020c	18	A	18.8 ± 2.2	G	EL; IL	Good (16)
Roell et al., 2020	12	Pro	20.7 ± 2.7	G	EL	Good (16)
Lukonaitienė et al., 2020	24	E; Y	18.8 ± 0.7	P; G	EL; IL	Good (15)
Staunton et al., 2020	9	Pro	26 ± 3	P	EL; IL	Good (15)
Coyne et al., 2021	13	E	29.0 ± 3.7	P; G	EL; IL	Good (18)
Espasa-Labrador et al., 2021	13	E; Y	16.3 ± 1	P	EL; IL	Good (16)
Vencúrik et al., 2021	18	Pro	18.8 ± 1.9	G	TM; IL	Good (19)
Duque et al., 2022	32	Y	NR	P	EL; IL	Good (17)
Gutiérrez-Vargas et al., 2022	32	Y	16.2 ± 1	G	EL; IL	Good (15)
Ibáñez et al., 2022	22	Pro	22.2 ± 2.6	P	EL	Good (17)
Portes et al., 2022	48	E; Y	16.8 ± 0.7	G	EL	Good (17)
Reina et al., 2022	10	Pro	24 ± 3	P; G	EL; IL	Good (16)
Arenas-Pareja et al., 2023	14	Pro	23 ± 3.1	P	EL; IL	Good (16)
Ferioli et al., 2023a	52	E	NR	G	TM	Good (17)
Ferioli et al., 2023b	52	E	NR	G	TM	Good (17)
Towner et al., 2023	11	E; Y	20.2 ± 1.3	P; G	EL	Good (16)
Willberg et al., 2023	37	Pro	23.5 ± 4.1	G	EL; IL	Good (15)

NR: not reported; A: amateur; E: elite; EL: external load; G: game; IL: internal load; P: practice; Pro: professional; TM: time-motion analysis; Y: youth

Table 2a. External load method, device, and outcome during basketball practice

Publication (year) (n; level; age)	Study-defined practice mode(s)	Observations by player; Total units; Session duration (minutes)	Device (Model, manufacturer)	Outcome
Herran et al., 2017 (n = 10; Y; 15 ± 1)	FCS SSG	1–2; 5*v*5: 10, 3*v*3: 6; 60	10 Hz GPS (MinimaxX v.4.0, Catapult Innovations)	Outcome by variables (3*v*3; 5*v*5) TD: 249.6 ± 32.8; 209.2 ± 35.8, TD/min: 49.9 ± 6.6; 41.8 ± 7.2 PL: 47.6 ± 7.4; 34.8 ± 8.6, V_{max}: 3.0 ± 0.4; 2.8 ± 1.1
Peterson and Quiggle, 2017 (n = 5; E; 20 ± 1)	FCS	NR; NR; NR	100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	Weekly player' average: PL: 813.1 ± 91.7, IMA: 191.0 ± 26.7 Weekly team' average: PL: 4065.4 ± 458.7, IMA: 954.9 ± 133.7
Reina et al., 2017 (n = 10; A; 21.7 ± 3.7)	SSG SG	SSG: 26, SG: 45; 122; 100	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Average outcomes (SSG; FG; 5*v*5) Impacts/min: 2.0 ± 0.5; 1.7 ± 0.7; 1.7 ± 1.4 Steps/min: 37.5 ± 9.8; 39.2 ± 9.6; 53.5 ± 8.7 Jumps/min: 1.6 ± 0.4; 1.45 ± 0.4; 1.8 ± 0.4
Staunton et al., 2018b (n = 9; Pro; 27 ± 5)	FCS	18; 162; NR	100 Hz tri-axial accelerometer (Link, Actigraph, Pensacola, FL, USA)	AvFNet: 293 ± 40 % total duration spent in each intensity zone: Sedentary: 45.4 ± 7.7, Very light: 18.2 ± 6.1, Light: 9.8 ± 3.3 Moderate: 9.0 ± 2.4, Vigorous: 11.0 ± 3.1, Maximal: 3.0 ± 0.8, Supramaximal: 3.7 ± 1.7
Coyne et al., 2019 (n = 12; E; 27.8 ± 3.6)	NR	NR; 1717; NR	Accelerometer (NR, Catapult Sports, Melbourne, Australia)	PL/min Data shown are the product of various calculations. Direct results obtained through control methods are not reported.
Reina et al., 2019b (n = 10; A; 21.7 ± 3.7)	SG	47; 155; TT: 75.75 ± 7.74 UT: 65.42 ± 6.83	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	PL/min: 0.9, Impacts/min: 1.7, Steps/min: 39.2, Jumps/min: 1.4
Reina et al., 2019c (n = 10; A; > 18)	FCS, SSG, ST, WD	120; 1200; TT: 13.8 ± 9.0 UT: 12 ± 8.4	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Average outcomes (min; max; AVG and SD) PL: 0.6; 46.8; 12.9 ± 7.9 SEL: 12.0; 1460.7; 277.4 ± 263.7
Reina et al., 2019d (n=12; Y; U13)	NR	35; 420; NR	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Steps; Jumps; PL (AU)

AU: arbitrary units; NR: not reported; 3*v*3: three versus three players; 5*v*5: five versus five players; A: amateur; Acc: accelerations; Acc/min: accelerations per minute; Acc_{avg}: average accelerations; Acc_{high}: high accelerations; Acc_{max}: maximal accelerations; AvFNet: average force net; DD: defensive drills; Dec: decelerations; Dec/min: decelerations per minute; Dec_{avg}: average decelerations; Dec_{high}: high decelerations; Dec_{max}: maximal decelerations; E: elite; ED: explosive distance covered; ED/min: explosive distance covered per minute; FCS: full court session; FG: friendly game; High-IMA: high inertial movement assessment; IMA: inertial movement assessment; IMU: inertial movement unit; Mono-PL: monotony Player Load index; MS: match simulation drills; OD: offensive drills; PL: Player Load (AU); Pro: professional; SD: skill-development drills; SEL: subjective external load; SG: simulated game; SSG: small-side game; ST: superiority task; Strain-PL: strain Player Load index; TA: total accelerations; TA/min: total accelerations per minute; TA_{max}: total maximal accelerations; TD: total distance covered; TD/min: total distance covered per minute; $TDAcc_{high}$: total distance covered through high accelerations; $TDDec_{high}$: Total distance covered through high decelerations; TO_{high}: jump high take-offs; TT: total time; U: under age; UT: useful time; UWD: ultra-wideband system; V_{avg}: average velocity; V_{max}: maximal velocity; WD: without defense drills; WU: warm-up drills; Y: youth

Table 2b. External load method, device, and outcome during basketball practice. Continued.

Publication (year) (n; level; age)	Study-defined practice mode(s)	Observations by player; Total units; Session duration (minutes)	Device (Model, manufacturer)	Outcome
Lukonaitienė et al., 2020 (n = 24, U20:12, U18: 12; E & Y; U20: 19.6 ± 0.8, U18: 18.0 ± 0.5)	FCS	U20: 15, U18: 18; 792; U20: 148.9 ± 59.4, U18: 146 ± 44.4	100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	Player' average outcomes (U20; U18) PL:58.9 ± 24.6; 68.0 ± 27.8, Mono-PL (AU): 4.7 ± 1.3; 5.3 ± 1.8. Strain-PL (AU): 965.5 ± 154.8; 1064.7 ± 217.7, Team' average outcomes (U20; U18) PL:706.4 ± 295.2; 816.4 ± 333.2, Mono-PL (AU): 4.7 ± 1.3; 5.3 ± 1.8, Strain-PL (AU): 965.5 ± 154.8; 1064.7 ± 217.7
Staunton et al., 2020 (n = 9; Pro; 26 ± 3)	NR	18 ; 162 ; 90-120	100 Hz tri-axial accelerometer (Link, Actigraph, Pensacola, FL, USA)	Average values by the type of a task (WU; SD; OD; DD; MS) Sedentary: 23 ± 4; 37 ± 5; 48 ± 5; 43 ± 4; 45 ± 4, Very light: 23 ± 1; 20 ± 2; 19 ± 2; 22 ± 2; 19 ± 2, Light: 16 ± 2; 11 ± 2; 9 ± 2; 10 ± 2; 9 ± 1, Moderate: 17 ± 1; 9 ± 1; 7 ± 0; 7 ± 1; 8 ± 1, Vigorous: 16 ± 1; 14 ± 1; 9 ± 1; 10 ± 1; 11 ± 1, Maximal: 3 ± 1; 4 ± 1; 3 ± 0; 3 ± 0; 3 ± 0, Supramaximal: 3 ± 1; 5 ± 2; 5 ± 2; 6 ± 1; 5 ± 2
Coyne et al., 2021 (n = 13; E; 29 ± 3.7)	NR	126.3; 1642; NR	Accelerometer (NR, Catapult Sports, Melbourne, Australia)	Total PL/min: 4.6 ± 2.0 PL/m average in practice: 4.1 ± 1.0 External weekly load: 2787 ± 772
Espasa-Labrador et al., 2021 (n = 13; E & Y; 16.3 ± 1)	FCS	35; 164; NR	Polar Pro Technology (Polar Team Pro, Polar Electro Oy, Finland)	Player' average outcomes TA: 1766 ± 10.0 TAmax: 258 ± 82.2 TA/min: 16.8 ± 2.4 Acc/min: 8.4 ± 1.2 Dec/min: 8.4 ± 1.2
Duque et al., 2022 (n = 32; Y; NR)	NR	3; NR; 90	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Player's average outcomes PL: 51.9 ± 10.0 PL/min: 1.3 ± 0.1
Ibáñez et al., 2022 (n = 22 ; Pro; 22.2 ± 2.6)	NR	10; NR; NR	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Average threshold by variable (Speed; Acc; Dec; Impacts): Very Low/Standing: < 2.3; < 0.5; > −0.4; < 1 Low/Walking: 2.3 to 5.3; 0.5 to 1.6; −0.37 to −1.1; 1 to 3 Moderate/Jogging: 5.3 to 9.3; 1.6 to 2.9; −1.1 to −2.1; 3 to 5 High/Running: 9.3 to 13.1; 2.9 to 4.3; −2.1 to −3.2; 5 to 7 Very high/Sprinting: 13.1 to 17.1; 4.3 to 6.7; −3.2 to −4.8; 7 to 10.

Table 2c. External load method, device, and outcome during basketball practice. Continued.

Publication (year) (n; level; age)	Study-defined practice mode(s)	Observations by player; Total units; Session duration (minutes)	Device (Model, manufacturer)	Outcome
Reina et al., 2022 (n = 10 ; Pro; 24 ± 3)	FCS	10; NR; 120	IMU and 6 UWB antennae (Wimu™, RealTrack Systems, Almería, Spain)	Player's average outcomes TD: 2532.0 ± 962.8; TD/min: 38.5 ± 8.4; ED: 313.6 ± 118.3; ED/min: 5.1 ± 2.3; Acc: 901.3 ± 260.6; Dec: 265.0 ± 73.4; Acc/min: 15.0 ± 3.2; Dec/min: 4.7 ± 2.1; V_{max}: 20.7 ± 1.6; V_{avg}: 4.4 ± 0.2; Jumps: 103.4 ± 46.0; Jumps/min: 1.6 ± 0.6; PL: 41.0 ± 14.6; PL/min: 0.6 ± 0.2
Arenas-Pareja et al., 2023 (n = 14; Pro; 23 ± 3.1)	FCS	14; NR; Warm-up: 21.5 ± 8.1, Main part: 67.5 ± 14.8	8 UWB antennae (Wimu™, RealTrack Systems, Almería, Spain)	TD: 4988.0 ± 986.5; 5046.7 ± 1122.0; 6087.0 ± 469.1; 5062.1 ± 1489.4; ED: 716.4 ± 273.2; 924.5 ± 378.2; 1426.7 ± 529.5; 861.4 ± 418.1; Acc: 2514.6 ± 568.2; 2670.6 ± 865.6; 2285.4 ± 1183.9; 2454.3 ± 791,8; Dec: 2523.1 ± 569.5; 2697.1 ± 837.1; 2328 ± 1183.9; 2488.3 ± 741.0; Acc_{max}: 6.8 ± 1.8; 7.8 ± 2.0; 8.3 ± 1.5; 8.1 ± 1.6; DecMax: 7.1 ± 1.8; 7.8 ± 1.8; 8.8 ± 0.9; 7.7 ± 1.6; Acc_{avg}: 1.1 ± 0.2; 1.5 ± 0.6; 1.9 ± 0.8; 1.5 ± 0.7; Dec_{avg}: 1.1 ± 0.2; 1.4 ± 0.5; 1.8 ± 0.8; 1.4 ± 0.6; Acc_{high}: 129.4 ± 113.3; 302.9 ± 243.2; 447.6 ± 367.4; 249.5 ± 256.8; Dec_{high}: 114.0 ± 90.2; 267.1 ± 216.9; 406.8 ± 322.4; 234.1 ± 229.3; $TDAcc_{high}$: 266.3 ± 180.2; 514.3 ± 364.4; 759.2 ± 545.4; 440.5 ± 381.1; $TDDec_{high}$: 253.7 ± 160.2; 476.5 ± 341.3; 704.3 ± 521.5; 437.3 ± 369.8; Sprints (n): 31.2 ± 18.3; 36.6 ± 20.9; 48.6 ± 22.5; 39.1 ± 21.9; V_{max}: 16.4 ± 2.1; 18.6 ± 5.1; 20.6 ± 4.2; 19.0 ± 6.6; PL: 53.9 ± 10; 52.2 ± 15.6; 45.3 ± 20.1; 55.0 ± 12.4
Towner et al., 2023 (n = 11; E & Y; 20.2 ± 1.3)	NR	102; NR; NR	IMU Catapult ClearSky T6 (NR, Catapult Sports, Melbourne, Australia)	Average of the team by season's period. These data include game data (8-h preseason; 20-h preseason; Non-Conference; Conference; Yearlong) PL: 428.7 ± 169.3; 469.9 ± 125.0; 532.2 ± 233.9; 496.4 ± 252.5; 492 ± 220.8 PL/min: 5.4 ± 2.6; 5.3 ±1.2; 5.4 ± 1.2; 5.3 ± 1.2; 5.3 ± 1.5 High-IMA: 19.7 ± 18.7; 33.8 ± 17.2; 40.3 ± 57.1; 33.8 ± 19.3; 33.7 ± 34.9 Jumps: 112.5 ± 106.7; 76.0 ± 34.7; 95.8 ± 63.3; 80.1 ± 55.3; 88.4 ± 65.6

Table 3a. External load method, device, and outcome during basketball competition

Publication (year) (n; level; age)	Study-defined competition mode(s)	Observations by player; Total units;	Device (Model, manufacturer)	Outcome
Peterson and Quiggle, 2017 (n = 5; E; 20 ± 1)	5*v*5 OG	NR; NR	100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	Weekly player' average: PL: 813.1 ± 91.7, IMA: 191.0 ± 26.7 Weekly team' average: PL: 4065.4 ± 458.7, IMA: 954.9 ± 133.7
Reina et al., 2017 (n = 10; A; 21.7 ± 3.7)	5*v*5 OG	8; 80	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Impacts/min: 1.7 ± 1.4, Steps/min: 53.5 ± 8.7, Jumps/min: 1.8 ± 0.4
Montgomery and Maloney, 2018 (n = 208; E & Y; 22.9 ± 5.6)	3*v*3 WCh 3*v*3 ECh 3*v*3 U18	NR 635	10 Hz GPS and 100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	TD: 856.7 ± 220.8 m; TD/min: 44.1 ± 9.6 $m \cdot min^{-1}$ Average by competition (WCh; ECh; U18): PL: 131.7 ± 31.2; 131.6 ± 29.7; 116.0 ± 29.0, PL/min: 6.6 ± 1.4; 6.3±1.4; 6.6 ± 1.4, VJ1: 5.3 ± 3.8; 5.0 ± 3.7; 5.3 ± 3.4, VJ2: 12.0 ± 5.3; 10.9 ± 5.2; 13.0 ± 5.8, VJ3: 2.4 ± 1.8; 2.5 ± 1.9; 2.5 ± 1.9, D1: 28.6 ± 9.1; 28.3 ± 9.8; 27.3 ± 9.9, D2: 8.8 ± 3.9; 9.1 ± 3.8; 8.8 ± 4.0, D3: 4.4 ± 2.4; 4.7 ± 2.3; 4.0 ± 2.2, A1: 20.5 ± 7.7; 21.5 ± 7.2; 18.5 ± 7.0, A2: 7.0 ± 3.2; 7.7 ± 3.4; 6.1 ± 3.3, A3: 5.6 ± 3.0; 6.2 ± 3.3; 4.3 ± 2.4, CoDL: 6.6 ± 3.2; 7.5 ± 3.8; 5.2 ± 3.4, CoDR: 4.7 ± 2.8; 4.7 ± 2.7; 4.0 ± 2.4
Staunton et al., 2018a (n = 10; Pro; 27.0 ± 5.0)	5*v*5 OG	18; 180	100 Hz tri-axial accelerometer (Link, Actigraph, Pensacola, Florida, United State of America)	AvFNet for each zone: Sedentary: 41.9 ± 17.2, Very light: 16.7 ± 3.2, Light: 9.5 ± 4.2, Moderate: 7.6 ± 3.2, Vigorous: 11.1 ± 5.9, Maximal: 3.7 ± 1.4, Supramaximal: 5.5 ± 2.5
Ransdell et al., 2019 (n = 6; E; 19.7 ± 1.5)	5*v*5 OG	NR; NR	100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	Average by season (PL; PL/min; High-IMA; Jumps) 2014–2015: 587.9 ± 165.3; 7.3 ± 1.0; 47.1 ± 16.5; 81.9 ± 24.0, 2015–2016: 682.7 ± 162.9; 7.4 ± 1.3; 54.2 ± 20.3; 85.8 ± 26.9 2016–2017: 678.1 ± 198.0; 6.4 ± 1.1; 52.1 ± 19.4; 92.4 ± 39.2, 2017–2018: 626.1 ± 131.1; 7.4 ± 0.9; 52.3 ± 14.2; 99.7 ± 38.2 4-year average: 655.6 ± 173.2; 7.1 ± 1.2; 52.1 ± 18.5; 89.8; 33.4

AU: arbitrary units; NR: not reported; 3v3: three versus three players; 5v5: five versus five players; A: amateur; A1: accelerations threshold 1; A2: accelerations threshold 2; A3: accelerations threshold 3; Acc: accelerations; Acc/min: accelerations per minute; Acc:Dec: accelerations and decelerations ratio;Acchor: horizontal maximal accelerations; Accmax: maximal accelerations; Accres: vector resultant accelerations; Accvert: vertical maximal accelerations; AvFNet: average force net; CoDL: change of direction to left; CoDR: change of direction to right; D0: distance covered between 0–6 km/h; D1: distance covered between 6–12 km/h; D2: distance covered between 12–18 km/h; D3: distance covered between 18–24 km/h; D4: distance covered at >24 km/h; Dec: decelerations; Dec/min: decelerations per minute; E: elite; ECh: European championship; ED: explosive distance covered; ED/min: explosive distance covered per minute; FG: friendly game; GPS: global positioning system; High-Acc/min: high accelerations per minute; High-Dec/min: high decelerations per minute; High-IMA: high inertial movement assessment; HIR: high-intensity-running; IMA: inertial movement assessment; IMU: inertial movement unit; Mono-PL: monotony Player Load index; OG: official game; PL: Player Load (AU); Pro: professional; Q: quarter of the game; SprintD: sprint distance; TD: total distance covered; TD/min: total distance covered per minute; U: under age; UWB: ultra-wide band indoor system; Vavg: average velocity; VJ1: vertical jump threshold 1; VJ2: vertical jump threshold 2; VJ3: vertical jump threshold 3; Vmax: maximal velocity; WCh: World championship; Y: youth

Table 3b. External load method, device, and outcome during basketball competition. Continued

Publication (year) (n; level; age)	Study-defined competition mode(s)	Observations by player; Total units;	Device (Model, manufacturer)	Outcome
(Reina et al., 2019a) (n = 48; Y; U18)	5*v*5 OG	3; 144	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Average by quarter (Q1; Q2; Q3; Q4) Acc: 156.3; 163.4; 158.3; 160.7 Dec: 153.0; 154.8: 148.0; 156.7 Duration of accelerations (ms): 2138.3; 2157.0; 2035.3; 2004.6) Maximal peak of acceleration (m/s^2): 2.5, -2.6; 2.6, -2.6; 2.5, -2.6; 2.6; -2.6)
Reina et al., 2019b (n = 10; A; 21.7 ± 3.7)	5*v*5 OG	8; 80	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	PL/min: 2.8, Impacts/min: 1.7, Steps/min: 54.0, Jumps/min: 1.8
Reina et al., 2019d (n = 12; Y; U13)	5*v*5 OG	8; 96	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	NR
Lukonaitienė et al., 2020 (n = 24, U20: 12, U18: 12; E & Y; U20: 19.6 ± 0.8, U18: 18.0 ± 0.5)	5*v*5 FG	U20: 5, U18: 5; U20: 60, U18: 60	100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	Average by team (U18; U20): PL: 816.36 ± 333.19; 706.37 ± 295.2, Mono-PL (AU): 5.29 ± 1.78; 4.68 ± 1.26, Strain-PL (AU): 1064.68 ± 217.66; 965.50 ± 154.82
Portes et al., 2020 (n = 48; Y; 17 ± 1)	5*v*5 OG	6; 288	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	TD: 2513 ± 1300, HID: 237 ± 170, SprintD: 14 ± 24, Acc: 370 ± 285, Dec: 273 ± 239, Acc/min: 9.1 ± 5.3, Dec/min: 6.5 ± 3.7, Ratio Acc:Dec: 1.6 ± 0.8; PL: 39 ± 21, PL/min: 1.0 ± 0.4
Reina et al., 2020a (n = 48; Y; U18)	5*v*5 OG	3; 144	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	NR
Reina et al., 2020b (n = 18; A & Y; 3*v*3: 17.9 ± 0.7, 5v5: 19.7 ± 3.7)	3*v*3 OG 5*v*5 OG	3v3: 3, 5v5: 8; 104 (3*v*3: n = 24; 5*v*5: n = 80)	1000 Hz tri-axial accelerometer (Wimu™, RealTrack Systems, Almería, Spain)	Average outcomes by competition (3*v*3; 5*v*5): Impacts: 7.5 ± 3.4; 1.7 ± 1.7, Steps: 44.4 ± 9.8; 53.3 ± 10.2, Jumps: 4.5 ± 1.9; 1.8 ± 1.0
Roell et al., 2020 (n = 12; Pro; 20.7 ± 2.7)	5*v*5 OG	NR; NR	100 Hz tri-axial accelerometer (OptimEye S5, Catapult Sports, Melbourne, Australia)	Acc_{max} in each plane (acc_{res}; acc_{hor}; acc_{vert}) 13.2 ± 1.3; 10.6 ± 1.3; 11.7 ± 1.2

Table 3c. External load method, device, and outcome during basketball competition. Continued.

Publication (year) (n; level; age)	Study-defined competition mode(s)	Observations by player; Total units;	Device (Model, manufacturer)	Outcome
Coyne et al., 2021 (n = 13; E; 29.0 ± 3.7)	5*v*5 OG	12.9; 167	10 Hz GPS and 100 Hz tri-axial accelerometer, gyroscope, and magnetometer (NR, Catapult Sports, Melbourne, Australia)	Total PL/min: 4.6 ± 2.0 PL/m average in competition: 9.72 ± 1.51 External weekly load: 2787 ± 772
Gutiérrez-Vargas et al., 2022 (n = 32; Y; Pro; 22.2 ± 2.6)	5*v*5 OG	NR; NR	8 UWB antennae and IMU (Wimu™, RealTrack Systems, Almería, Spain)	Average values according positions (guards; forwards; centers): TD (m/min): 69.2 ± 12.9; 70.8 ± 19.6; 67.4 ± 19.1, D0: 31.3 ± 4.9; 30.3 ± 6.8; 27.4 ± 6.7, D1: 26.0 ± 6.5; 26.3 ± 9.2; 23.9 ± 8.3, D2: 10.5 ± 3.7; 12.7 ± 5.4; 15.2 ± 6.4, D3: 1.2 ± 1.0; 1.3 ± 1.1; 0.9 ± 1.1, D4: 0.04 ± 0.1; 0.01 ± 0.1; 0.0 ± 0.0, Acc: 32.0 ± 13.2; 26.2 ± 3.5; 24.8 ± 3.12, Dec: 31.9 ± 13.2; 26.1 ± 3.5; 24.7 ± 3.1, V_{max}: 5.1 ± 0.6; 5.0 ± 0.7; 4.8 ± 0.6, Jumps: 0.6 ± 0.3; 0.7 ± 0.3; 1.1 ± 0.6
Portes et al., 2022 (n = 48; E & Y; 16.8 ± 0.7)	5*v*5 OG	NR; NR	100 Hz IMU and 20 Hz 6 UWB antennae (Wimu™, RealTrack Systems, Almería, Spain)	Average values according positions (guards; forwards; centers): TD: 440.7 ± 454.2; 684.5 ± 518.3; 447.3 ± 424.4, HIR: 38.9 ± 49.8; 64.7 ± 64.0; 46.9 ± 54.6, Sprint: 2.7 ± 7.8; 5.9 ± 2.0; 3.3 ± 10.0, Acc: 68.2 ± 85.0; 97.8 ± 97.1; 63.9 ± 80.0, Dec: 32.0 ± 40.7; 60.8 ± 46.6; 37.8 ± 35.2, Acc/min: 7.5 ± 7.3; 8.3 ± 6.8; 6.8 ± 6.4, Dec/min: 4.5 ± 3.7; 5.3 ± 3.5; 4.5 ± 3.8, Acc:Dec: - 0.8 ± 2.5; - 0.3 ± 2.3; - 0.15 ± 1.6, Jumps: 10.5 ± 13.3; 18.0 ± 17.9; 14.5 ± 17.2, Jumps/min: 1.2 ± 1.3; 1.5 ± 1.3; 1.6 ± 1.7, PL: 7.1 ± 7.4; 10.5 ± 8.3; 6.8 ± 6.8, PL/min: 0.8 ± 0.6; 0.9 ± 0.6; 0.8 ± 0.8
Reina et al., 2022 (n = 10 ; Pro; 24 ± 3)	5*v*5 OG	1; NR	IMU and 6 UWB antennae (Wimu™, RealTrack Systems, Almería, Spain)	Player' average outcomes TD: 3531.6 ± 310.5; TD/min: 69.2 ± 3.0; ED: 458.7 ± 69.9; ED/min: 9.0 ± 1.0; Acc: 944.7 ± 81.4; Dec: 940.9 ± 80.1; Acc/min: 18.5 ± 1.1; Dec/min: 18.4 ± 1.1; V_{max}: 19.4 ± 1.6; V_{avg}: 5.2 ± 0.2; Jumps: 33.9 ± 16.0; Jumps/min: 0.7 ± 0.3; PL: 58.9 ± 9.5; PL/min: 1.2 ± 0.2
Willberg et al., 2023 (n = 37; Pro; 23.5 ± 4.1)	5*v*5 OG 3*v*3 OG	84; NR	100 Hz IMU (Vector Elite Vest, Catapult Sports, Melbourne, Australia) and 10 Hz UWB antennae (Vector 7, Catapult Sports, Melbourne, Australia)	Player's average by type of event (5*v*5; 3*v*3): TD: 3633.1 ± 1480; 933.8 ± 219 TD/min: 70; NR, PL: 420.1 ± 162.2; 95.3 ± 25.9, PL/min: NR, EE: 35.9 ± 18.6; 14.1 ± 6.5, Jumps: 29.2 ± 15.1; 16.6 ±7.5, High-Acc/min: 8.5 ± 6.2; 3.8 ± 2.5, High-Dec/min: 5.1 ± 3.3; 3.7 ± 2.2

Table 4a. Time-motion analysis event, sample, methods and details of analysis during basketball practice competition.

Publication (n; level; age)	Event (details)	Observations by player; Total units	Quantification external load		Details of analysis
			Device or software (manufacturer)	Variables	
Matthew and Delextrat, 2009 (n = 9; A; 25.8 ± 2.5)	Competition (5*v*5 OG)	9; 81	Stationary immobile camera (JVC-x400, Hong Kong, China)	Jump; Sprint; Run; Jog; Stand/walk; LIS; MIS; HIS; Total of actions	Quarters analysis
Narazaki et al., 2009 (n = 6; E; 20.0 ± 1.3)	Competition (5*v*5 OG)	6; 36	Stationary camera (ZR20, Canon U.S.A. Inc., Lake Success, New York, USA)	Stand; Walk; Run; Jump	Periods analysis; male and female comparative
Delextrat & Calleja-González, 2012 (n = 9; Pro; 24.3 ± 4.1)	Practice (SSG; DT; TT; FCS); Competition (5*v*5 OG)	5; 45	Stationary immobile camera (JVC-x400 Hong Kong, China)	Playing game; Jump; Sprint; Run; Jog; HIS; MIS; LIS; Stand/walk; Total of actions	
Klusemann et al., 2012 (n = 8; Y; 17.4 ± 0.7)	Practice (SSG: 2*v*2; 4*v*4)	19; 152	Notational video analysis software (SportsCode Elite, Sydney, Australia)	Technical element: total elements, dribble, pass, close range shot, mid-range jump shot, 3-point shot, rebound ball screen External loads: Total movement, stand/walk, Jog, Run, Sprint, LIS, MIS, HIS and jump	Participants analysis; Half and full court analysis; time analysis
Scanlan et al., 2012 (n = 12; A; 22.0 ± 3.7)	Competition (5*v*5 OG)	8; 96	Two wide-angle Baslet A602FC color cameras (Basler Vision Technologies, Ahrensburg, Germany); Labview frame-by-frame manual tracking system (National Instruments, Austin, TX, USA)	Stand/walk; Jog; Run; Sprint; LIS; HIS; Dribble; Jump*; Upper body*; Total of actions	Analysis per quarters and halves and backcourt and frontcourt
Oliveira-Da-Silva et al., 2013 (n = 96; E; 27.8 ± 4.4)	Competition (5*v*5 OG)	4; 96	Adobe Premiere 5.0	Stand/walk; Jog; Run; LIS; MIS; Sprint; HIS; Jump; Total of actions	Position analysis
Conte et al., 2015 (n = 6; E; 27 ± 4)	Competition (5*v*5 OG)	5; 30	Fixed camera (Sony HD AVCHD HDR-CX115, Sony, Tokyo, Japan); Dartfish software 6.0 (Dartfish, Fribourg, Switzerland)	Stand/walk; Jog; Run; Sprint; Jump; LIS; MIS; HIS	Live time, stoppage time, transfer phases, half and full court, distance of actions, with and without ball, lineal, curve and change of directions actions

NR: not reported; 2*v*2: two versus two players; 4*v*4: four versus four players 5*v*5: five versus five players; A: amateur; DT: defensive task; E: elite; FCS: full court session; High-SM: high-intensity specific movements; HIS: high-intensity shuffle; LIS: low-intensity shuffle; MIS: medium-intensity shuffle; OG: official game; Pro: professional; SSG: small-side game; TT: technical task; U: under age; Y: youth

Table 4b. Time-motion analysis event, sample, methods and details of analysis during basketball practice competition.

Publication (n; level; age)	Event (details)	Obs. by player; Total units	Quantification external load		Details of analysis
			Device or software (manufacturer)	Variables	
Delextrat et al., 2015 (n = 42; Pro; 25.9 ± 4.3)	Competition (5*v*5 OG)	3; 18	Video camera (25Hz); LINCE multiplatform sport analysis software (Observesport, Lleida, Spain)	Stand, Walk, Jog, Run, Sprint, Jump, LIS, MIS, HIS, Pass, Static, Total-recov, Total-low, Total-mod, Total-high, Total actions	Analysis per position and quarters
Scanlan et al., 2015 (n = 12; Pro; 22.0 ± 3.7)	Competition (5*v*5 OG)	36; 432	Two wide-angle Baslet A602FC color cameras (Basler Vision Technologies, Ahrensburg, Germany); Labview frame-by-frame manual tracking system (National Instruments, Austin, TX, USA).	Stand/walk; Jog; Run; Sprint; LIS; HIS; Dribble; Jump*; Upper body*; Total of actions	Backcourt and frontcourt and work:rest analysis; male and female comparison
Vencúrik et al., 2021 (n = 18, U19: 10, 2nd division: 8; Pro; U19: 17.6 ± 1 2nd division: 20 ± 2.8)	Competition (5*v*5 OG)	U19: 5; 50, 2nd div.: 9; 72	Video camera (streaming); Dartfish TeamPro 6.0 software (Dartfish, Fribourg, Switzerland)	Effective or ineffective dribbling and passing skills	Analysis per effectiveness, possession duration, quarters and defensive pressure
Ferioli et al., 2023a (n = 52; E; NR)	Competition (3*v*3 OG)	NR; NR	NR; SICS VideoMatch Basket, version 5.0.5 (Bassano del Grappa, Italy)	Frequency and duration of: Stand/Walk; LIS; MIS; HIS; Sprint; High-SM; Jumps	Comparison of values between victory and defeat and between group and final phase
Ferioli et al., 2023b (n = 52; E; NR)	Competition (3*v*3 OG)	NR; NR	NR; SICS VideoMatch Basket, version 5.0.5 (Bassano del Grappa, Italy)	Frequency and duration of: Stand/Walk; LIS; MIS; HIS; Sprint; High-SM; Jumps	Comparison of values between male and female players

NR: not reported; 2*v*2: two versus two players; 4*v*4: four versus four players 5*v*5: five versus five players; A: amateur; DT: defensive task; E: elite; FCS: full court session; High-SM: high-intensity specific movements; HIS: high-intensity shuffle; LIS: low-intensity shuffle; MIS: medium-intensity shuffle; OG: official game; Pro: professional; SSG: small-side game; TT: technical task; U: under age; Y: youth

Table 5a. Summary of physical action outcomes during competition and practice.

Competition events description in different levels					
Publication	Matthew and Delextrat, 2009 (n = 9; A; 25.8 ± 2.5)	Delextrat and Calleja-González, 2012 (n = 9; Pro; 24.3 ± 4.1)	Scanlan et al., 2012 (n = 12; A; 22.0 ± 3.7)	Oliveira-Da-Silva et al., 2013 (n = 96; E; 27.8 ± 4.4)	Conte et al., 2015 (n = 6; E; 27 ± 4)
Actions	Frequency of action; Relative frequency of action per minute	Frequency of action; Relative frequency of action per minute played	Frequency of action	Frequency of action per competition (Euroleague; WCh; Mean between both events)	Frequency of action; duration (s) of action; percentage of live time (%) spent in each action
Stand/walk	151 ± 26; 5.0	170.8 ± 61.4; 7.0 ± 1.1	436 ± 44	198 ± 9.2; 225 ± 11.22; 11.5 ± 10.2	205 ± 42; 35.4 ± 2.0; 7.42 ± 10.6
Jog	67 ± 17; 2.2	74.0 ± 14.9; 3.2 ± 0.8	551 ± 67	176 ± 15.1; 172 ± 17.9; 174 ± 16.5	73 ± 20; 12.8 ± 3.0; 2.7 ± 2.2
Run	52 ± 19; 1.7	40.3 ± 13.8; 1.7 ± 0.4	295 ± 41	231 ± 16.2; 177 ± 21.1; 204 ± 18.6	63 ± 16; 11.0 ± 1.8; 3.1 ± 1.6
Sprint	49 ± 17; 1.7	26.1 ± 15.6; 1.06 ± 0.5	108 ± 20	141 ± 21.4; 54 ± 18.0; 97.5 ± 19.7	44 ± 15; 7.8 ± 2.2; 1.8 ± 0.8
Jump	35 ± 11; 1.0	26.8 ± 18.1; 1.1 ± 0.6	43 ± 6	24 ± 3.2; 54 ± 18.0; 23 ± 6.2	19 ± 10; 3.4 ± 1.5; 0.5 ± 0.1
LIS	117 ± 14; 3.8	88.6 ± 26.8; 3.63 ± 0.4	41 ± 5	227 ± 7.8; 206 ± 14.3; 216.5 ± 11.1	91 ± 23; 15.5 ± 2.0; 1.7 ± 1.2
MIS	123 ± 45; 4.0	48.8 ± 21.1; 2.0 ± 0.5		212 ± 11; 192 ± 19.1; 202 ± 15.0	56 ± 20; 9.6 ± 2.5; 1.8 ± 1.0
HIS	58 ± 19; 1.9	28.6 ± 17.5; 1.1 ± 0.4	22 ± 5	100 ± 6.3: 50 ± 11.1; 75 ± 8.7	25 ± 10; 4.5 ± 1.5; 1.6 ± 0.9
Dribble			34 ± 2		
Pass					
Upper body			220 ± 18		
Total	652 ± 128; 21.2		1750 ± 186	1309 ± 11.2; 1098 ± 15.2; 1203.6 ± 13.2	

NR: not reported; 2*v*2: two versus two players; 4*v*4: four versus four players 5*v*5: five versus five players; A: amateur; DT: defensive task; E: elite; FCS: full court session; High-SM: high-intensity specific movements; HIS: high-intensity shuffle; LIS: low-intensity shuffle; MIS: medium-intensity shuffle; OG: official game; Pro: professional; SSG: small-side game; TT: technical task; U: under age; Y: youth

Table 5b. Summary of physical action outcomes during competition and practice. Continued

	Competition events description in different levels				
Publication	Delextrat et al., 2015 (n = 42; Professional; 25.9±4.3)	Scanlan et al., 2015 (n = 12; Professional; 22.0±3.7)	Vencúrik et al., 2021 (n = 18, U19: 10, 2nd div.: 8; Professional; U19: 17.6 ± 1 2nd div.: 20 ± 2.8)	Ferioli et al., 2023a (n = 52; E; NR)	Ferioli et al., 2023b (n = 52; E; NR)
Actions	Relative frequency per minute; mean duration (s) per action; percentage of live time (%) spent in each action	Relative frequency per minute of action; duration (s/min); distance covered (m/min)	Frequency of action (effective; ineffective)	Frequency of action; duration of actions (% of total time) by final result and phase	Frequency of action per minute during live playing time (% total time); Frequency of action per minute during ball possession (% total time)
Stand/walk	Stand: 6.4 ± 1.1; 2.33 ± 1.32; 30.2 ± 3.9 Walk: 2.1 ± 0.8; 2.13; 9.5 ± 4.5	10.7 ± 0.9; 21.4 ± 0.6; 11.2 ± 0.2		Win: 5.0 ± 1.6; 14.1 ± 6.4, Loss: 4.8 ± 1.7; 13.3 ± 6.5, Group: 5.0 ± 1.6; 13.9 ± 6.5, Final: 4.7 ± 1.7; 13.5 ± 6.7	5.0 (14.1); 0.2 (2.8)
Jog	4.1 ± 1.2; 31.7 ± 5.2; 24.0 ± 9.0	13.6 ± 1.3; 21.3 ± 04; 37.4 ± 1.2			
Run	1.2 ± 0.6; 31.4 ± 4.8; 4.9 ± 2.6	7.3 ± 0.9; 10.1 ± 0.3; 45.7 ± 1.4			
Sprint	0.2 ± 0.2; 2.2 ± 0.8; 0.6 ± 0.6	2.7 ± 0.5; 2.4 ± 0.4; 22.7 ± 4.4		Win: 2.0 ± 1.0; 2.9 ± 1.4 Loss: 2.2. ± 1.1; 3.4 ± 1.8 Group: 2.0 ± 1.0; 2.9 ± 1.5 Final: 2.3 ± 1.6; 3.4 ± 1.8	
Jump	1.1 ± 0.3; 26.6 ± 3.6; 2.3 ± 1.3	1. ± 0.1; NR; NR		Win: 3.4 ± 1.0; 3.5 ± 1.1 Loss: 3.2 ± 0.9; 3.1 ± 0.9 Group: 3.4 ± 1.0; 3.35 ± 1.0 Final: 3.2 ± 0.9; 3.17 ± 0.9	
LIS	4.6 ± 2.1; 25.6 ± 3.6; 16.8 ± 8.8	1.0 ± 0.2; 1.9 ± 0.4; 1.8 ± 0.6		Win: 44.9 ± 5.9; 16.7 ± 2.8 Loss: 44.1 ± 5.8; 44.4 ± 5.8 Group: 45.4 ± 6.0; 45.4 ± 6.0 Final: 43.7 ± 5.4; 43.7 ± 5.4	15.2 (44.6); 2.0 (29.0)
MIS	1.2 ± 1.1; 27.4 ± 4.4; 2.8 ± 2.6			Win: 16.7 ± 2.8; 16.7 ± 2.8 Loss: 17.2 ± 2.9; 17.2 ± 2.9 Group: 16.5 ± 2.9; 16.5 ± 2.9 Final: 17.4 ± 2.8; 17.4 ± 2.8	8.2 (16.8); 1.5 (20.0)
HIS	0.3 ± 0.6; 28.1 ± 2.4; 0.7 ± 1.4	0.5 ± 0.1; 0.4 ± 0.1; 1.2 ± 0 .3		Win: 24.3 ± 4.8; 24.3 ± 4.8 Loss: 25.1 ± 4.7; 25.1 ± 4.7 Group: 24.2 ± 4.8; 24.2 ± 4.8 Final: 25.4 ± 4.6; 25.4 ± 4.6	11.9 (24.6); 4.3 (48.2)
Dribble		0.8 ± 0.0; 2.5 ± 0.3; 8.4 ± 0.3	487; 64		
Pass			761; 153		
Upper body		5.4 ± 0.6; NR; NR			
Total	24.1 ± 3.5	44.1 ± 5.3; 2.5 ± 0.3; 128.5 ± 5.3	1248; 217	Win: 40.2 ± 3.4; NR Loss: 40.4 ± 3.4; NR Group: 40.3 ± 3.5; NR Final: 40.3 ± 3.3; NR	40.2 (NA); 8.0 (NA)

NR: not reported; 2*v*2: two versus two players; 4*v*4: four versus four players 5v5: five versus five players; A: amateur; DT: defensive task; E: elite; FCS: full court session; High-SM: high-intensity specific movements; HIS: high-intensity shuffle; LIS: low-intensity shuffle; MIS: medium-intensity shuffle; OG: official game; Pro: professional; SSG: small-side game; TT: technical task; U: under age; Y: youth

Table 5c. Summary of physical action outcomes during competition and practice. Continued.

Practice events		
Publication	Narazaki et al., 2009 (n = 6; Elite; 20.0 ± 1.3)	Klusemann et al., 2012 (n = 8; Youth; 17.4 ± 0.7)
Actions	Frequency; Total duration by each movement	Frequency of action (4*v*4; 2*v*2; half-court; full-court; 2x5 min; 4x2.5 min)
Stand/walk	Stand: 23.2 ± 13.2; 1.6±0.9 Walk: 112.0 ± 4.5; 10.6 ± 0.3	125 ± 23; 120 ± 18; 137 ± 14; 103 ± 11; 119 ± 20; 124 ± 20
Jog		66 ± 12; 63 ± 11; 63 ± 13; 68 ± 10; 65±11; 66 ± 11
Run	89.3 ± 0.6; 6.2 ± 0.7	35 ± 10; 35 ± 10; 34 ± 9; 37 ± 11; 33 ± 8; 38 ± 8
Sprint		11 ± 5; 15 ± 5; 13 ± 6; 13 ± 6; 12 ± 5; 14 ± 6
Jump	15.8 ± 5.7; 0.3 ± 0.1	16 ± 6; 26 ± 5; 23 ± 8; 18 ± 6; 20 ± 7; 22 ± 7
LIS		42 ± 10; 39 ± 12; 45 ± 9; 32 ± 9; 39 ± 12; 40 ± 12
MIS		75 ± 17; 72 ± 19; 81 ± 13; 62 ± 20; 69 ± 17; 77 ± 18
HIS		8 ± 4; 13 ± 6; 11 ± 5; 7 ± 3; 9 ± 6; 12 ± 6
Dribble		
Pass		
Upper body		
Total		378 ± 51; 382 ± 52; 407 ± 30; 340 ± 35; 20 ± 7; 22 ± 7

NR: not reported; 2*v*2: two versus two players; 4*v*4: four versus four players 5*v*5: five versus five players; A: amateur; DT: defensive task; E: elite; FCS: full court session; High-SM: high-intensity specific movements; HIS: high-intensity shuffle; LIS: low-intensity shuffle; MIS: medium-intensity shuffle; OG: official game; Pro: professional; SSG: small-side game; TT: technical task; U: under age; Y: youth

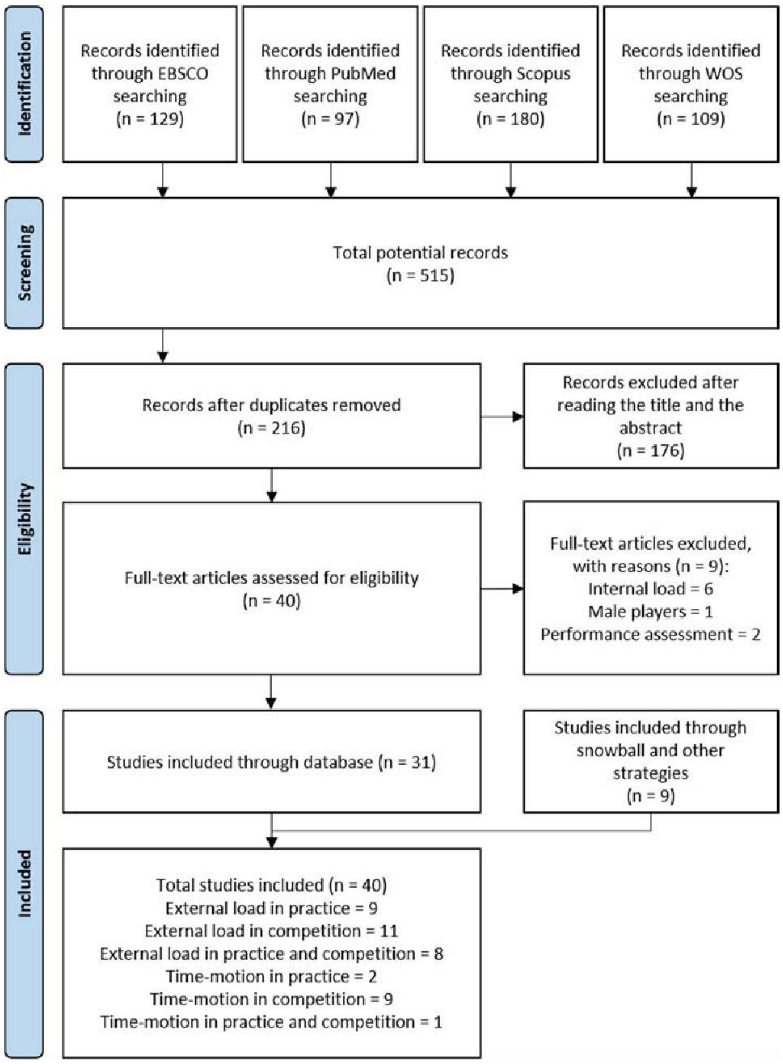

Figure 1. PRISMA flowchart selection of studies.

Discussion

The current systematic review is the first to summarize the scientific evidence available and analyse reported outcomes in relation to the external load monitoring in female basketball players. Moreover, this review includes an evaluation of the methodological quality of the included studies. The most relevant results identified in this study related to external loads will be discussed. There was great heterogeneity in methods used for monitoring external loads in female basketball players. There were also a variety of variables and values reported, which made it difficult to compare values across the included studies. During the analysis of the included studies, it was noticed that 85% of publications were from the last decade, with 70% articles published in the last five years (2018–2023). This trend coincided with a shift in research methods from time-motion analysis to the use of positioning and accelerometry devices. While this change has been previously observed in basketball research in general (Russell et al., 2020), our findings suggest that it has also occurred specifically in women's basketball. This growing interest in studying external load monitoring in women's basketball could be interpreted as an increased focus on improving athletic performance. Furthermore, this shift in methods from time-motion analysis to sensor-based technologies, such as accelerometers, may be due to their ability to provide more comprehensive and real-time data compared to video-based analyses, which can be time-consuming and resource-intensive (Russell et al., 2020). These results suggest that there may be a greater allocation of financial resources towards women's basketball research.

External Load during Female Basketball Practice

During practice sessions, it was observed that video analysis was used only in two publications (Klusemann et al., 2012; Narazaki et al., 2009) in comparison to sensor-based methods implemented on players (such as inertial motion units, GPS, etc.). New and more sophisticated sensor-based methods allow for the quantification of both intensity and the direction of movement without requiring an evaluator to categorize particular actions (Crang et al., 2021). This not only streamlines the data collection process, but also eliminates the evaluator bias, yielding, despite its limitations (Nicolella et al., 2018), accurate values for movement magnitudes. These monitoring systems have made it possible to assess the physical demand of specific tasks as well as of the overall training session. The primary variable used to quantify external loads in most studies was Catapult's PlayerLoad™ (PL), a cumulative metric that integrates accelerations in all three axes expressed in arbitrary units (Nicolella et al., 2018).

The PL value is expressed in arbitrary units, as the sum of different movements in different directions and magnitudes. This is a "raw" value, which generates a limitation in understanding of the specific actions of basketball players, as it does not precisely identify which actions contribute most to the increase in the PL value. The data obtained from PL were treated differently by authors: 1) PL of the entire session (Lukonaitienė et al., 2020), 2) PL per minute (PL/min) (Coyne et al., 2019, 2021; Reina et al., 2019a), 3) PL by task (Herran et al., 2017), 4) weekly average of PL (Peterson and Quiggle, 2017). Despite this, the authors of this systematic review want to highlight two metrics: 1) total PL of the session, and 2) PL relative to training time. The first metric helps understand the volume of training, while the second metric represents its density. Both metrics allow coaches and researchers to compare sessions globally, compare players, or even particular tasks. Regarding the latter point, interesting findings have been reported in this systematic review, as one publication showed that tasks involving defenders had a greater external load than those without defenders (Reina et al., 2019b). Regardless of this, it appears that beyond a certain level of participants, the total load decreased, which leads to a conclusion that under equal time and space conditions, 5v5 tasks were less demanding than 3*v*3 tasks (Herran et al., 2017; Reina et al., 2019b). This could be due to the availability of space per player. A larger number of participants does not allow for covering such long distances to reach high speeds, a phenomenon already observed in male players (Bredt et al., 2020). This makes us reflect on the need to identify specific variables in 5*v*5 situations during practice (accelerations, speed thresholds, jumps, etc.), as it has been reported in competition (Montgomery and Maloney, 2018; Portes et al., 2020). Although there is still a lack of evidence to support this approach, these initial data can help with the appropriate organization and the design of tasks during the training process, leading to optimal physiological adaptations in the preparation of the players. Moreover, the density of the workload, which expresses the relationship between work and rest, could be a better indicator of competition demands, facilitating the understanding of physiological responses (McLaren et al., 2018). In relation to the results of this review, it was observed that a higher competitive level presented a greater density of training, something that has also been observed in male players (Petway et al., 2020). However, further research is needed to establish whether density should be studied under the total time or the useful time of training (Reina, et al., 2019b).

On the other hand, some studies reported weekly average player load values, which resulted in their wide range (706.4 ± 295.2 to 816.4 ± 333.2 AU) (Lukonaitienė et al., 2020; Peterson and Quiggle, 2017). Averaging several sessions over the week may not be the best way to detect acute changes in loading. Nevertheless, this measure could be useful in determining reference values for managing external loads across a season. Other publications have reported average session values per player (between 58.9 ± 24.6 and 68.0 ± 27.8 AU). This metric has similar limitations to the weekly average, although it may allow for optimizing loads in the next practice session.

External Loads during a Basketball Game

Based on publications included in this systematic review, over half of the studies evaluated physical demands in official basketball competition. In order to accurately monitor position metrics in basketball, it is more appropriate to use the LPS than to the GPS (Russell et al., 2020). However, few studies in basketball utilized this positioning system to evaluate loads. Only one publication indicated the use of LPS in female basketball players (Portes et al., 2020). This study showed that the player's mean total distance covered (TD) was 2513 ± 1300 m, which was similar to values in male players (Petway et al., 2020). Similarity of outcomes between different populations could be attributed to the rules of basketball that do not differ by sex, such as the lengths of possession (24 s) and the playing court dimensions (15 x 28 m). In other sports where possession of the ball is not time-dependent, there may be more differences between female and male athletes. This idea is supported by the values obtained in the 3*v*3 competition, where values of the distance covered were much lower (856.7 ± 220.8 m) (Montgomery and Maloney, 2018). 3*v*3 games of basketball are played on a half-court (15 x 14 m) for a maximum of 14 minutes or 21 points scored. Another metric of volume identified above was PL; however, only one publication reported such data. The study showed that averages were lower in competition compared to 5*v*5 tasks during practice, where values were 39 ± 21 AU in youth athletes (Portes et al., 2020). These lower values and wider ranges could be explained by methodological aspects not described in the publication. Previous studies on male players recommended to only include players who played a minimum number of minutes in the data analysis (García et al., 2020). For 3*v*3 competition, there were no differences between elite (World Championship: 131.74 ± 31.15 AU; European Championship: 131.60 ± 29.66 AU) and youth athletes (U-18: 115.95 ± 28.99 AU) with regard to the external load (Montgomery and Maloney, 2018). The similarities between competitive levels coupled with the inherent differences between 3*v*3 and traditional basketball indicate that 3*v*3 basketball has very specific physical demands which can be attributed to a different set of rules (space, duration and substitutes).

For intensity assessment in basketball competition, using speed thresholds-based metrics such as high-intensity-distance has been described as a valid method (Portes et al., 2020; Scanlan et al., 2015). Slightly lower values of intensity have been observed for male players compared to female ones when using the same speed thresholds (14–21 $km \cdot h^{-1}$) for both sexes (female players: 237 ± 170 m, and male players: 453 ± 263 m) (Portes et al., 2020). Only one another study assessed high-intensity actions, but a wide intensity range (10.8–25.2 $km \cdot h^{-1}$) was used, which likely resulted in the capture of very diverse actions that may have been of lower intensity (Scanlan et al., 2015). Similarly, with sprinting, there were different criteria for intensity thresholds (> 21 $km \cdot h^{-1}$ or > 25.2 $km \cdot h^{-1}$). More research is needed to establish specific intensity thresholds in female basketball players in order to better understand physical demands given the limitations discussed in this systematic review. This applies to both practice and competition. Contrary to the metrics identified in training and described previously, different actions were studied during competition: 1) accelerations and decelerations, 2) acceleration:deceleration ratio, and 3) duration of accelerations. The above-mentioned variables could be of great help in understanding the acute post-match physiological response (e.g., muscle damage/soreness) and neuromuscular status (e.g., jump power loss) in female basketball (Koyama et al., 2022). This information could guide the individualization of better training and recovery programs throughout the week. Training and recovery could be further enhanced through the analysis of additional metrics, such as steps, impacts and jumps.

During competition, it can be difficult to compare groups or to establish a reference value because of the wide variety of ways the intensity data are collected, used, and presented. Future research could focus on comparing the same group of players during different events (e.g., specific tasks or practice vs. competition) or at specific points in the season.

Time-Motion Analysis in Female Basketball Practice and Competition

Time-motion analysis is a widespread manual notational technique to classify the movement patterns and intensities during sport events, despite its subjectivity and problems with validation and reliability (Abdelkrim et al., 2007). The ability to analyse these activities is related to the experience and reliability of the evaluator, especially those linked to movement intensity. This is an important point to consider when interpreting and applying the reference values summarized in this systematic review. Previous studies have already identified limitations with the implementation of this technique for load evaluation in basketball (Russell et al., 2020), which are primarily due to the fact that specific skills, such as dribbling or changes of direction, are not assessed in most cases.

Although this method has some limitations, it is useful for providing basic information with few resources. Semi-automated video analysis techniques exist, which simplify and optimize this process (Fox et al., 2017). The total or density of jumps per minute are examples of useful metrics, as they are easy to identify. In competition, the number of vertical actions is small, regardless of the level, with an average range of 19 to 43 jumps (Conte et al., 2015; Delextrat and Calleja-González, 2012; Matthew and Delextrat, 2009; Oliveira-Da-Silva et al., 2013; Scanlan et al., 2012), and a density close to one jump per played minute (Delextrat and Calleja-González, 2012; Matthew and Delextrat, 2009; Scanlan et al., 2015). Although all reported values could be used as a reference, it is advisable to study the specific demands in each context and adapt the training process to prepare the players for those demands. For example, it may be useful to expand the use of descriptive terms to elaborate on the type of a jumping action (e.g., bilateral, unilateral, take-off, landing, etc.). Understanding the types of jumps can be as useful in making training decisions as the overall quantity of jumps.

On the other hand, in the application of video analysis, actions where players are walking or standing can be quantified by classifying those actions as rest or standing. The observed metrics can help establish the density or a ratio between work and rest time, thus providing more information that can be used to improve the training process. In this case, the duration of these actions would be a better approximation of the density of training or competition rather than the sum of actions (Delextrat et al., 2015). Our systematic review identified that players at the highest competitive level performed more walking or standing actions during competition (from 170 to 205 occurrences) compared to athletes at lower levels. However, these findings are based on a small sample size, and more research is necessary to fully comprehend how the best basketball players manage rest moments. Possible explanations for this trend could be the higher intensity of play at the highest competitive level, which might require athletes to take short bouts of recovery between high-intensity actions (Rodríguez-Alonso et al., 2003). Additionally, athletes at higher levels of competition may have more knowledge and experience of the game, allowing them to be more efficient in their high-intensity actions and reducing the physical demand (Delextrat et al., 2015). Further investigation is necessary to confirm and expand upon the preliminary findings, which could be of significant interest as it offers valuable insights into the workload density during competition.

Methodological Limitations and Considerations for the Future

The current systematic review presents several limitations that could largely be the consequence of varied data collection and reporting from included studies. The main limitation is related to the great heterogeneity of methods and variables used to describe volume, intensity and density variables in women's basketball, which makes the use of these data complex. We recommend evaluating the current consensus on load monitoring (Bourdon et al., 2017). Secondly, there is a lack of information on methodological aspects. The understanding of external loads, especially in practice events, would improve if more information was provided, including: 1) the number of participants in the tasks, 2) the number and duration of interruptions, 3) the size of space used, 4) active time relative to total time, etc. (Petway et al., 2020). Finally, in relation to the samples used, it is necessary to communicate how they were obtained (convenience, random, etc.), as well as their characteristics (competitive level, years of experience, etc.), and loss of participants, if necessary. Despite one of the studies aiming to measure physical demands at different stages of the menstrual cycle (Arenas-Pareja et al., 2023), none of the included publications fulfilled any of the recommended guidelines for studying female athletes. These guidelines have been established recently for a better description of samples consisting of female athletes (Elliott-Sale et al., 2021).

This systematic review showed that there was great heterogeneity in methods and variables used in external load monitoring. It is necessary to establish a consensus about methods used and data analysis to standardize volume and intensity output. Nevertheless, the literature seems to indicate that there are higher loads, through PL values, at higher competitive levels and greater frequency of high-intensity actions (e.g., jumps and sprints). At the same time, elite players spend more time standing and walking, indicating greater efficiency and intensity in actions. Total distance and high-intensity distance covered had wide ranges (TD_{5v5}: 2513 ± 1300 m, HID_{5v5}: 237 ± 170 m, and TD_{3v3}: 856.7 ± 220.8 m). During practice, unopposed tasks had lower values of PL. Increasing the number of participants appeared to increase external loads. Small-sided games were the most demanding task, while 5*v*5 practice was the least demanding (PL_{5v5}: 34.8 ± 8, PL_{3v3}: 47.6 ± 7.4, TD_{5v5}: 209.2 ± 35.8 m, and TD_{3v3}: 249.3 ± 2.8 m). Although more scientific evidence is needed to understand external loads in female basketball players, this review presents a reference for researchers and practitioners.

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ORCID iD:

Javier Espasa-Labrador: 0000-0002-4686-4248

Julio Calleja-González: 0000-0003-2575-7168

Alicia M. Montalvo: 0000-0003-1805-3170

Azahara Fort-Vanmeerhaeghe: 0000-0002-5071-1084

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Publicación II

Monitoring Internal Load in Women's Basketball via Subjective and Device-Based Methods: A systematic Review

Espasa-Labrador, J., Fort-Vanmeerhaeghe, A., Montalvo, A. M., Carrasco-Marginet, M., Irurtia, A., & Calleja-González, J. (2023). Monitoring Internal Load in Women's Basketball via Subjective and Device-Based Methods: A Systematic Review. *Sensors* (Basel, Switzerland), *23*(9), 4447. https://doi.org/10.3390/s23094447.

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Systematic Review

Monitoring Internal Load in Women's Basketball via Subjective and Device-Based Methods: A Systematic Review

Javier Espasa-Labrador [1], Azahara Fort-Vanmeerhaeghe [2,3], Alicia M. Montalvo [4], Marta Carrasco-Marginet [1], Alfredo Irurtia [1,*] and Julio Calleja-González [5,6]

1 INEFC-Barcelona Research Group on Sport Sciences (GRCE), National Institute of Physical Education of Catalonia (INEFC), University of Barcelona (UB), 08038 Barcelona, Spain
2 FPCEE and FCS Blanquerna, SAFE Research Group, Ramon Llull University, 08022 Barcelona, Spain
3 Segle XXI Female Basketball Team, Catalan Federation of Basketball, 08915 Esplugues de Llobregat, Spain
4 College of Health Solutions, Arizona State University, Phoenix, AZ 85004, USA
5 Department of Physical Education and Sport, Faculty of Education and Sport, University of the Basque Country, (UPV/EHU), 01007 Vitoria, Spain
6 Faculty of Kinesiology, University of Zagreb, 10110 Zagreb, Croatia
* Correspondence: airurtia@gencat.cat; Tel.: +34-934255445

Abstract: The monitoring of internal load in basketball can be used to understand the effects and potential physiological adaptations caused by external load. The main aim of this systematic review was to identify the methods and variables used to quantify internal load in female basketball. The studies included different populations and events: youth athletes, elite, and amateur players. Subjective methods included using the rating of perceived exertion (RPE) method, and sensor-based methods included monitoring the cardiac response to exercise, using heart rate (HR) as the primary metric. The results showed that the HRAvg exhibited a wider range of values during training than during competition, and different metrics were used to evaluate internal load, such as HRMax, HRmin, %HRMax, total time and % of time spent in different HR zones (2–8 zones), Banister's TRIMP, and summated HR zones. RPE and HR metrics were the most commonly used methods. However, the use of multiple metrics with little standardization resulted in significant heterogeneity among studies, limiting meaningful comparisons. The review provides a reference for current research on female basketball. Future research could address this limitation by adopting more consistent measurement protocols standardizing the use of metrics.

Keywords: physiological response; monitoring; female basketball

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1. Introduction

With the ever-increasing demand for optimal performance in basketball, researchers and clinicians are constantly striving to discover new ways to gain a competitive edge, leading to significant advancements in the field of basketball science [1]. Recently, there has been an increase in interest in managing and monitoring internal and external load to reduce injury risk and enhance performance [2]. There are two types of loads: (1) external load, or the amount of work done in a time period or bout of activity, and (2) internal load, or the psycho-physiological response to external load. Because external load is task-dependent, it is position-dependent in sport. Conversely, internal load depends on the psycho-physiologic and intrinsic factors in the athlete, such as motivation, stress, fatigue, cognitive capacity, age, gender, sport experience, and physical condition [3]. Due to the intermittent nature of team sports, it is imperative to understand internal load and quantify its relationship with a dose-response of activity for precise training planning [4]. The most common methods for quantifying internal load in team sports are biochemical parameters (e.g., blood lactate concentration [BLC]), oxygen consumption (VO2), heart rate (HR) activity, and the rating of perceived exertion (RPE) [5]. Among these, HR activity and RPE can be assessed through various metrics, such as Banister's training impulse ($TRIMP_B$) and Edward's summated heart rate zones score (SHRZ) for HR activity, and Foster's proposal, multiplying session RPE by session time (sRPE) for RPE. These metrics express their data in arbitrary units (AU), and provide a quantitative measure of the internal load experienced by the athlete, allowing for a more precise assessment of training adaptations and injury risk.

The existing literature has described methods for quantifying internal load in a range of team sports [6], including girl's and women's basketball. Research on internal load in sports aims to improve understanding of the impact of internal load and individual physiological responses to different stimuli. This understanding can maximize positive training adaptations, minimize the negative effects of training, and enhance performance. However, the majority of research on internal load has focused on male basketball players [7], and more research is needed on female basketball players. In recent years, exercise physiology research has emphasized the physiological characteristics and differences between women and men [8]. However, there is a dearth of scientific evidence on the internal response of female athletes to various sports, including basketball [6,9]. It is crucial to identify the most effective methods for evaluating internal load in female basketball players of different competitive levels and age groups to improve training planning and load management. Despite the existence of systematic reviews on internal load monitoring methods in female basketball players [10,11], there is no previous review on the techniques used to measure or report internal load in this population.

The primary objective of this systematic review is to identify the common methods and metrics used to quantify internal load in female basketball players during training and competition, by level of competition and age. The secondary objectives are to identify potential normative values and critique the heterogeneity of the methods used.

2. Materials and Methods

2.1. Search Strategy

This is a systematic review focused on monitoring physiological responses during training and competition in female basketball players at varying levels of competition. The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis protocols (PRISMA-P®) statement [12].

A structured search was carried out in the EBSCO, PubMed, Scopus, and Web of Science. The search encompassed all articles published until 31 January 2023. The following Boolean search equation was used to find the relevant articles: ("female" OR "woman") AND "basketball" AND ("monitoring" OR "training" OR "internal" OR "physiological") AND "load". The search strategy was modified for the PubMed database, namely through the use of medical subject headings (MeSH) and free-text words for key concepts related to the monitoring of load in the training or competition of the athletes under investigation. The specific search strategy used in PubMed was: (("female" [MeSH Terms] OR "female" [All Fields]) OR ("women" [MeSH Terms] OR "women" [All Fields])) AND ("basketball" [MeSH Terms] OR "basketball" [All Fields]) AND (("monitoring" [MeSH Terms] OR "monitoring" [All Fields]) OR ("training" [MeSH Terms] OR "training" [All Fields]) OR ("internal" [All Fields] OR "physiological" [All Fields])) AND ("load" [MeSH Terms] OR "load" [All Fields]). Furthermore, the reference sections of all the relevant articles were also examined by applying the snowball strategy [13]. The search for published studies was independently performed by 2 different authors (J.E-L. and A.F-V.).

2.2. Inclusion and Exclusion Criteria

To select relevant articles, the PICOS model was used to determine the inclusion criteria: P (Population): "female basketball athletes", I (Intervention): "monitoring internal load practice or competition", O (Outcome): "physiological response measurements", and S (study design): "original studies published in journals" [12]. There were no filters applied to the athlete's physical fitness level, race, or age to increase the power of the analysis. Study participants were categorized into several groups: elite, professional, amateur, and youth players. The elite group was defined by their participation in the Women's Basketball Association (WNBA), NCAA Division I, Euro League Women and FIBA International Competition. Professional was defined by athletes competing in the first and second divisions in any continent, but were over 19 years old. Amateur level was considered under the level of those mentioned previously. Youth competition was considered for studies in which the participants were all 19 years of age or younger. This clustering has been designed following the previous literature [14].

The systematic bibliographic review included studies that met the following criteria: (1) original investigation, (2) populations were healthy female players at the elite, professional, amateur, or youth levels of any age, (3) articles presented data from monitoring basketball training or competition, including 3v3 and regular 5v5 competition formats, and articles described physiological responses or perceptual measures (internal load) to determine load dose. Friendly games were analyzed jointly with competitive events, while simulated games were analyzed jointly with training events. Only English publications were included. The investigation applied exclusion criteria to experimental protocols, which included: (1) post-event assessments related to recovery or performance status (excluded publications that utilized methods or devices to assess variables before or after the basketball event, such as assessing the loss of neuromuscular function during a jump or the time it took to return to baseline heart rate), (2) validation of research instruments through basketball (the emphasis is on load data to prevent publications that solely compare devices), (3) studies on performance tests in female basketball players (to explore the usage of devices in real situations, during practice and competition), (4) studies on wheelchair basketball, (5) studies with injured participants (injured basketball players may display values that are heterogeneous or differ from the typical responses seen in healthy players), (6) studies for clinical or therapeutic purposes, and (7) doctoral theses, conference oral and poster presentations (primarily focused on peer-reviewed publications of the highest quality).

2.3. Study Selection

Two authors (J.E-L. and A.F-V.) identified papers through database searching, and then duplicates were removed. Next, the authors reviewed the titles and abstracts of the remaining publications to determine eligibility for full-text review. All studies that met the inclusion criteria were retrieved and reviewed in full, and any disagreements were resolved by a third reviewer (J.C-G.).

2.4. Data Extraction

Once the inclusion/exclusion criteria were applied to each study, the following data were extracted: (1) study source (author/s and year of publication); (2) type of event studied (training or competition); (3) population of the sample, indicating the number of participants, age, and level of activity (elite, professional, semi-professional, amateur, and youth players); (4) observational sample (observation by player and total observation); (5) methods and devices utilized for the quantification of load; (6) variables identified for each method; and (7) outcomes reported for each variable. In the publications in which the variables to be extracted were not shown, information was requested from the corresponding author via e-mail. The final outcomes of the interventions were extracted independently by two authors (J.E-L. and A.F-V.) using a spreadsheet (Microsoft Excel 2019, version 23, Microsoft Inc., Seattle, WA, USA). Subsequently, disagreements were resolved through discussion until a consensus was reached or third-party adjudication (J.C-G.).

2.5. Quality Assessment and Risk of Bias

To assess the quality of publications, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies was used [15]. Two authors independently assessed the methodological quality and risk of bias (J.E-L. and M.C-M.) of each investigation included for the analysis. Disagreements were resolved by third party evaluation (A.I.).

The following scale was used to classify study quality: (1) good quality (>14 points, low risk of major or minor bias); (2) fair quality (7–4 points, moderate risk of major bias); and (3) poor quality (<7 points, high risk of major bias). The score was obtained through the 22 items of the STROBE checklist. No risk of bias assessment was used because this review was descriptive, and we did not report or discuss effects, associations, or prevalence.

In order to assess inter-rater agreement, Cohen's Kappa coefficient was calculated for the total scores of the studies based on STROBE.

3. Results

3.1. Search Strategy

A selection process was carried out, and a total of 503 potential records were identified through database searches. From these initial 503 articles, 294 duplicates were removed, resulting in a total of 209 publications that underwent title and abstract review. Thereafter, a total of 135 articles were removed after screening the titles and abstracts, leaving 74 articles for full-text assessment of eligibility. Subsequently, a total of 37 articles were eliminated from the review process after full-text peer-reviewed evaluation. The topics and number of studies that were excluded were as follows: three studies were not pursuing the aim to assess the internal load, twelve studies were excluded due to unsuitable outcomes (external load monitoring, resistance training, recovery monitoring, and performance assessment), four studies involving male players were excluded due to inappropriate subjects for inclusion criteria, ten studies were excluded due to non-English language, and five studies were excluded due to unsuitable design (bibliographic review and congress communications). Consequently, 37 studies met the previously defined inclusion criteria and were included in this final systematic review. After a complete snowball search strategy [13], a total of seven more publications were added [16–22], resulting in a total of forty-four studies included in this systematic review. Figure 1 presents the details of all processes and results obtained by the search strategy.

3.2. Populations and Events Studied

Table 1 summarizes the data in relation to the populations and events studied. Regarding the participants' level of competition, a total of 16 studies included youth athletes, with 12 studies collecting data during training [4,16,20,21,23–30] and 8 studies collecting data during competition [22,26,27,29–33]. Additionally, seven studies investigated the internal load in elite players during training [4,18,27,34–36] and six studies investigated the internal load in elite players during competition [26,31,35–38]. Among the professional players, 13 publications monitored the physiological response, with 7 studies monitoring it during practice [28,39–44] and 7 monitoring it during competition [32,39,41,42,45–47]. Finally, 12 studies investigated amateur players, with 5 studies monitoring them during practice [48–51] and 10 studies monitoring them during competition [49,51–56]. One of the included publications did not specify the level of competition [57].

Nineteen articles investigated the physiological response of female basketball players only during practice [4,16,20,21,23,25,28,34,39–41,43,44,48,50,57–60], while fourteen publications examined internal load only during competition [17,22,31,33–35,37,45,46,52,54,55,61,62] and eleven studies analyzed internal load in both events [24,26,27,29,32,35,36,47,51,53,56]. Among the included studies, 24 reported the type of tasks [4,16,20–29,34,39–44,49,51,53,56–60]. Of the studies that mentioned specific tasks, two publications simulated competition demands during training [24,53]. Regarding competition monitoring, a total of 28 publications recorded data in the 5v5 format [17–19,22,24,26,27,29–38,42,45–47,49,51–

56,61,62], while only 3 studies measured the competition in the 3v3 format [31,37,62], where all were collected during official competition. Among all studies investigating the 5v5 format, there was one friendly match [26].

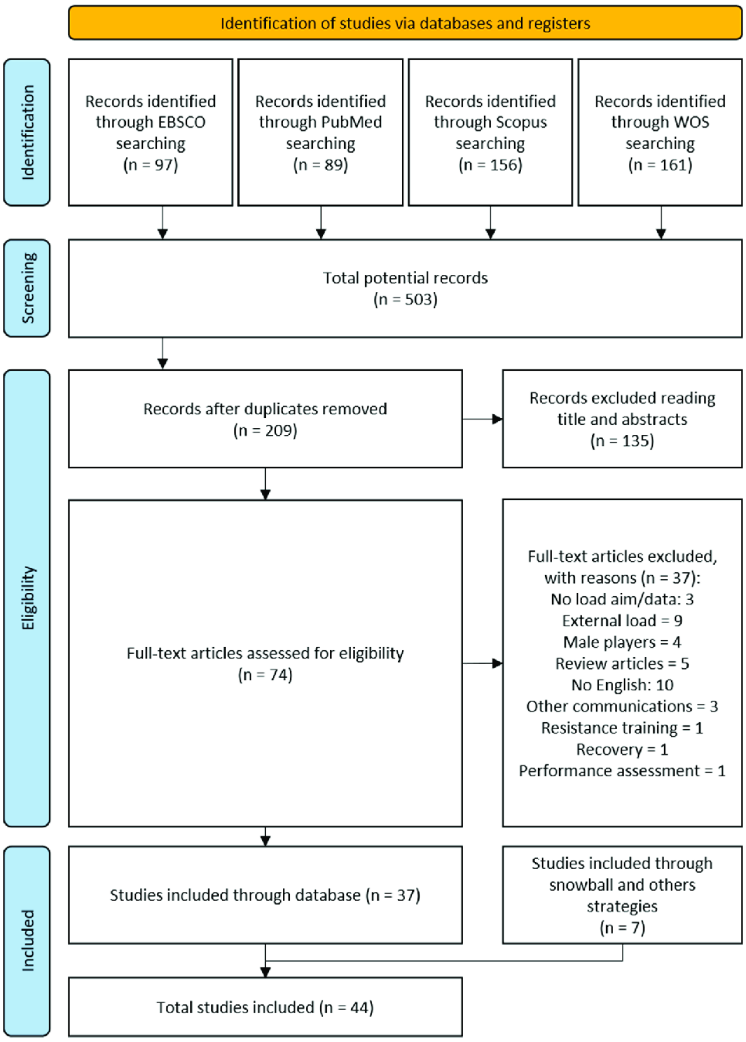

Figure 1. PRISMA diagram.

3.3. *Subjective Monitoring Load Methods*

Table 2 shows all the studies that used subjective methods to monitor internal load. A total of 28 publications used the RPE method as the internal monitoring method [4,16,19,21–23,25–27,29,31,34,36,37,39–44,47,48,50,51,54,56–58]. Some authors used the value reported by the players as a metric for analysis. Among these, 19 used this method to measure load in practice [19,21–23,25,27,31,35,37,40,43,44,48,50,55–58], showing a wide data range (2.9–7 AU), while 13 articles described the use of this method in games [19,22,26,27,31,36,37,42,44,47,51,54,56], with a shorter range in both competition formats (5v5: 3.9–6; 3v3: 5.3–5.9 AU). The closed range in the 5v5 format used the 6–20 scale (14.3–15.2 AU).

On the other hand, other authors multiplied this value by the practice or match time [4,16,21,25–27,29,34,36,39,41,42,47,50,51,57,58]. One of the most commonly reported metrics was the average session load per player, which exhibited a wide range (253–942 AU). Additional calculations were also observed, such as the team average per session, weekly sum, or average. Finally, few authors described the method or tool used to obtain this subjective value. Notably, those researchers who obtained the value through a mobile app [4,26,42,47], computer [51], or paper and pencil [25] provided some details on the methodology. The timing of data collection was described in a limited number of papers [4,37,44,56].

3.4. Sensor-Based Monitoring Load Methods

Table 3 shows all the studies that used sensor-based methods to quantify internal load. The majority of studies included in this systematic review that used sensors to evaluate the physiological response of female basketball players relied on monitoring players' cardiac response to exercise (27 of 32). With regard to the devices, only four studies provided complete information on the manufacturer, sampling frequency, and body placement (wrist, chest, or upper body) [4,34,35,37]. These sensors were used during practice sessions [4,20,23,28,34,44,48,50,58,60], games [17,19,31,33,35,37,45,46,52,55,61,62], or both events [24,26,30,32,35,47,49,53,57]. Heart rate was the most commonly used method to assess physiological response, although a variety of metrics were obtained and used to measure and evaluate the internal load, including the average HR (HR_{Avg}), maximum HR (HR_{Max}), minimum HR, percent of maximum HR ($\%HR_{Max}$), percent of average HR ($\%HR_{Avg}$), total time, or percentage of time spent in different HR zones (2–8 zones), $TRIMP_B$, and SHRZ.

During training, the HR_{Avg} exhibited a wider range of values than during competition, with readings ranging from 127.9 to 183.2 beats per minute (bpm) and 144.1 to 145.9 bpm, respectively. In the case of HR_{Max}, a similar range was observed between training and competition across different populations, with recorded minimums ranging from approximately 175 to 198 bpm. In addition, the observed $\%HR_{Max}$ was slightly lower during training sessions (72.95%) compared to competition (>81.2%). Finally, the use of indices based on HR data was summarized by $TRIMP_B$ and SHRZ. For the former, the individual average values (61.7 AU) and team sum values (214–304 AU) were found for each session of practice. Regarding SHRZ, the average range per player and session during training was between 162–352 AU, which was higher than the values during competition (68–80 AU).

A few studies explored other devices to obtain additional information about players' physiological response to exercise. All these results are summarized in Table 4. Blood lactate analysis was used in four studies during matches, showing a range from 3.2 to 5.7 in different levels of competition [19,31,52], and one study during practice [44], while one study evaluated VO2 during competition, with average values of 33.4 $\pm$ 4 mL/kg/min (66.7 $\pm$ 7.5% of individual maximal oxygen consumption) [19]. Additionally, one publication employed equations based on heart rate data to estimate calorie consumption during competition [61].

3.5. Quality Assessment and Risk of Bias

The publications in this review were classified into three categories based on their STROBE score. Of the total 44 studies, 28 were considered good quality, while 16 were fair. Table 1 displays the STROBE score and qualification of each study. The resulting coefficient was 0.863, indicating substantial agreement between rater 1 and rater 2. The significance level was below <0.001. In addition, only 0.51% (5 out of 968) of items were rated differently by the two reviewers, and the third reviewer's criteria were used to resolve any discrepancies.

Table 1. Basic characteristics of publications.

Publication	*n*	Level	Age	Event Registered	Method	Study Quality (Rate)
Anderson et al. (2003) [16]	12	Y	18–22	P	S	Good (15)
Matthew et al. (2009) [52]	9	A	25.8 ± 2.5	G	DB	Fair (14)
Narazaki et al. (2009) [19]	6	E	20.0 ± 1.3	P	S; DB	Fair (14)
Delextrat et al. (2012) [39]	9	P	24.3 ± 4.1	P; G	S	Fair (14)
Klusemann et al. (2012) [23]	8	Y	17.4 ± 0.7	P	S; DB	Good (16)
Scanlan et al. (2012) [17]	12	A	22.0 ± 3.7	G	DB	Good (15)
Atli et al. (2013) [20]	12	Y	15.5 ± 0.5	P	DB	Good (15)
Azpiroz et al. (2013) [22]	87	Y	U12	G	S	Fair (13)
Nunes et al. (2014) [58]	19	E	26.0 ± 5.0	P	S; DB	Good (16)
Abad et al. (2016) [24]	15	Y	16.9 ± 1.1	P	DB	Fair (12)
Vencúrik et al. (2016) [45]	10	Pro	20.4 ± 2.8	G	DB	Fair (10)
Legg et al. (2017) [21]	10	Y	18 ± 2	P	S	Fair (14)
Messias et al. (2017) [57]	8	NR	20 ± 1	P	S	Fair (12)
Vallés Ortega (2017) [40]	12	P	21.9 ± 4.8	P	S	Fair (13)
Vallés Ortega et al. (2017) [54]	12	A	17.1 ± 0.7	G	S	Fair (13)
Batalla et al. (2018) [55]	10	A	21.3 ± 2.7	G	DB	Fair (14)
Cruz et al. (2018) [41]	10	P	17.2 ± 0.4	P	S	Good (15)
Montgomery et al. (2018) [31]	208	E; Y	22.9 ± 5.6	G	S; DB	Good (16)
Sánchez et al. (2018) [59]	6	A	14.3 ± 0.5	P	S; DB	Fair (13)
Sanders et al. (2018) [35]	10	E	19.8 ± 1.3	G	DB	Good (16)
Coyne et al. (2019) [18]	12	E	27.8 ± 3.6	P	S	Good (17)
Lupo et al. (2019) [34]	15	E	16.7 ± 0.5	P	S	Good (15)
Paulauskas et al. (2019) [42]	29	Pro	21.0 ± 5.0	P; G	S	Good (17)
Reina et al. (2019) [49]	10	A	21.7 ± 3.7	P; G	DB	Good (18)
Reina et al. (2019) [30]	12	Y	U13	P; G	DB	Good (15)
Sanders et al. (2019) [35]	13	E	19.6 ± 1.3	P; G	DB	Good (15)
Vala et al. (2019) [46]	17	Pro	23.4 ± 2.1	G	DB	Fair (12)
Kraft et al. (2020) [50]	-	A	-	P	S	Fair (14)
Lastella et al. (2020) [25]	11	Y	17.3 ± 0.9	P	S	Good (16)
Lukonaitene et al. (2020) [26]	24	E; Y	18.8 ± 0.7	P; G	S; DB	Good (15)
Otaegi et al. (2020) [27]	19	Y	16.1 ± 0.7	P; G	S	Good (15)
Sansone et al. (2020) [51]	11	A	22.0 ± 3.0	P; G	S	Good (17)
Stauton et al. (2020) [43]	9	Pro	26 ± 3	P	S	Good (15)
Suárez-Iglesias et al. (2020) [28]	10	Pro; Y	18.6 ± 3.5	P	DB	Good (15)
Adrianova et al. (2021) [61]	10	Pro	183.9 ± 8.7	G	DB	Fair (10)
Brini et al. (2021) [44]	12	Pro	24.8 ± 1.8	P	S; DB	Good (16)
Coyne et al. (2021) [36]	13	E	29.0 ± 3.7	P; G	S	Good (18)
Espasa-Labrador et al. (2021) [4]	13	E; Y	16.3 ± 1	P	S; DB	Good (16)
Piñar et al. (2021) [47]	13	Pro	25.2 ± 7.3	G	S; DB	Good (17)
Senbel et al. (2021) [29]	NR	Y	NR	P; G	S	Fair (11)
Vencúrik et al. (2021) [32]	18	Pro; Y	18.8 ± 1.9	G	DB	Good (19)
Batalla-Gavalda et al. (2022) [56]	10	A	21.3 ± 2.7	G	S; DB	Good (18)
Gutiérrez-Vargas et al. (2022) [33]	32	Y	16.2 ± 1	G	DB	Good (15)
Willberg et al. (2022) [39]	37	E	23.5 ± 4.1	G	S; DB	Good (15)

NR: not reported; A: amateur; Y: youth; Pro: professional; E: elite; P: practice; G: game; S: subjective methods; DB: device-based monitoring methods.

Table 2. Internal load monitoring subjective perception-based method.

Publication (*n*; Level; Age)	Event		Observation		Method	Metrics	Tool(s) and Methodology	Outcome
	Practice Game	Study-Defined Mode(s)	Obs. by Player	Statistical Units				
Anderson et al. (2003) [16] (12; Y; A; 18–22)	P	NR	NR	NR	RPE (1–10)	sRPE	NR	NR
Narazaki et al. (2009) [19] (6; E; 20.0 ± 1.3)	G	5v5 OG	6	36	RPE (6–20)	RPE	NR	Player's average: 14.3 ± 1.9
Delextrat et al. (2012) [39] (9; Pro; 24.3 ± 4.1)	P	FCS, SSG, DT, TT	5	45	RPE (1–10)	sRPE	NR	NR
Klusemann et al. (2012) [23] (8; Y; 17.4 ± 0.7)	P	SSG (2v2; 4v4)	19	152	RPE (1–10)	RPE	NR	Player's average by task format: 4v4; 2v2; Half court; Full court; 2 × 5 min; 4 × 2.5 min 6 ± 2; 8 ± 2; 6 ± 2; 7 ± 2; 7 ± 2; 7 ± 2
Azpiroz et al. (2013) [22] (87; Y; U12; 16.9 ± 1.1)	G	5v5 OG	NR	NR	RPE (1–10)	RPE	NR	Player's average: 4.48 ± 1.65
Nunes et al. (2014) [58] (19; E; 26 ± 5)	P	FCS	NR	NR	RPE (1–10)	RPE; sRPE	NR	Player's average: RPE: 3.9 ± 1.5 sRPE: 321 ± 127
Legg et al. (2017) [21] (10; Y; 18 ± 2)	P	NR	NR	NR	RPE (1–10)	sRPE	NR	Player's average values by moment of season: Pre-season: 3195 ± 1083 Mid-season: 4344 ± 1376
Messias et al. (2017) [57] (8; A; 20 ± 1)	P	TaT; TeT	42	336	RPE (1–10)	RPE; sRPE	NR	Weekly team's average: RPE: 3.9 ± 0.9 sRPE: 413 ± 163.8
Vallés Ortega (2017) [40] (12; Pro; 21.91 ± 4.81)	P	FCS	NR	NR	RPE (1–10)	RPE	NR	Team's average: 3.12 ± 0.54
Vallés Ortega et al. (2017) [54] (12; A; 17.08 ± 0.67)	G	5v5 OG	6	50	RPE (1–10)	RPE	NR	Team's average: 4.16 ± 1.05
Cruz et al. (2018) [41] (10; Pro; 17.2 ± 0.4)	P	FCS	NR	NR	RPE (1–10)	sRPE	NR	Weekly team's sum: 1584.3 ± 237.4
Montgomery et al. (2018) [31] (208; E, Y; 22.9 ± 5.6)	G	3v3 OG	NR	635	RPE (1–10)	RPE	NR	Player's average by competition: Wch; ECh; U18 RPE: 5.3 ± 0.3; 5.8 ± 0.6; 5.9 ± 0.6
Sánchez et al. (2018) [59] (6; A; 14.3 ± 0.5)	P	SSG	2	12	RPE (1–10)	RPE	NR	Player's average: 5.80 ± 1.23
Coyne et al. (2019) [18] (13; E; 29.0 ± 3.7)	P; G	P: NR G: 5v5 OG	126.3	1642	RPE (1–10)	RPE; sRPE	NR	RPE average: 5.53 ± 1.67 RPE average in practice: 5.37 ± 1.62 Weekly load: 4588 ± 1587 Games data: RPE average 5.53 ± 1.67 RPE average in competition: 7.11 ± 1.22 Weekly load: 4588 ± 1587
Lupo et al. (2019) [34] (15; E; 16.7 ± 0.5)	P	FCS	19	268	RPE (1–10)	sRPE	NR	Player's average by session: strength; conditioning; technique sRPE: 521 ± 25.6; 555 ± 34.8; 514 ± 20.5
Paulauskas et al. (2019) [42] (29; Pro; 21 ± 5)	P; G	P: FCS G: 5v5 OG	96–144	2784–4176	RPE (1–10)	sRPE	Personal mobile device using Cloud-based software (Google Forms, Menlo Park, CA, USA)	Weekly sRPE player's average: 1722 ± 715 Weekly sRPE player's average during game clustered: Low playing time group: 720.3 ± 200.9 High playing time group: 903.1 ± 208.9
Kraft et al. (2020) [50] (NR; NR; NR)	P	NR	NR	124	RPE (1–10)	RPE; sRPE	NR	Player's average: RPE: 5.1 ± 1.8 SRPE: 711 ± 282

Table 2. *Cont.*

Publication (*n*; Level; Age)	Event		Observation		Method	Metrics	Tool(s) and Methodology	Outcome
	Practice Game	Study-Defined Mode(s)	Obs. by Player	Statistical Units				
Lastella et al. (2020) [25] (11; Y; 17.3 ± 0.9)	P	FCS	111	1221	RPE (1–10)	sRPE	Paper and pencil	Session's average clustered by type: LTLS: 274 ± 136 MTLS: 576 ± 221 HTLS: 1186 ± 309
Lukonaitene et al. (2020) [26] (24; E, Y; 18.8 ± 0.7)	P; G	P: FCS G: 5v5 FG	33	792	RPE (1–10)	sRPE	Personal mobile device using Cloud-based software (Google Forms, Menlo Park, CA, USA)	Data include practice and game average Team's average: U20; U18 sRPE: 617.29 ± 328.24; 942.82 ± 436.51
Otaegi et al. (2020) [27] (19; Y; 15 ± 0.7)	P; G	P: FCS G: 5v5 OG	50	478	RPE (1–10)	RPE; sRPE	Ask personally by coach	Team's average by teams: U15; U16 Daily RPE: 2.9 ± 0.3; 3.1 ± 0.6 Daily sRPE: 253 ± 27; 259 ± 50 Week sum sRPE: 10.9 ± 1.9; 13.9 ± 3.0 Week sum sRPE: 879 ± 140; 1073 ± 260 Games data: RPE (U15; U16): 3.6 ± 1.2; 4.5 ± 1.0 sRPE (U15; U16): 316 ± 115; 378 ± 96
Sansone et al. (2020) [51] (11; A; 22.0 ± 3.0)	P; G	P: FCS G: 5v5 OG	40	40	RPE (1–10)	sRPE	Registered individually with laptop	Player's average during practice: 428 ± 114 Weekly sRPE player's average: 1561 ± 177 NR data during games
Stauton et al. (2020) [43] (9; Pro; 26 ± 3)	P	WU; SD; OD; DD; MS	NR	NR	RPE (1–10)	RPE	NR	Player's average by type of task: WU; SD; OD; DD; MS 4.8 ± 0.1; 6.5 ± 0.2; 6.0 ± 0.1; 7.4 ± 0.0; 7.4 ± 0.0 Player's average by session: 6.42 ± 0.1
Brini et al. (2021) [44] (12; Pro; 24.8 ± 1.8)	P	SSG	NR	NR	RPE (1–10)	RPE	RPE: after each SSG and 30 after practice, NR tool	Player's average: 7.0 ± 0.8
Coyne et al. (2021) [36] (13; E; 29.0 ± 3.7)	P; G	FCS G: 5v5 OG	NR	NR	RPE (1–10)	sRPE	RPE: 30′ after event; NR	Daily average: 648 ± 496 Weekly average (including practice and game): 4588 ± 1597
Espasa-Labrador et al. (2021) [4] (13; E, Y; 16.3 ± 1)	P [39]	FCS	35	164	RPE (1–10)	sRPE	Quanter Mobile App (Kvantia, Helsinki, Finland)	Average per session: sRPE: 765.3 ± 174.9; SHRZ: 276.1 ± 61.9; TRIMPB: 61.7 ± 10.1
Piñar et al. (2021) [37] 13; Pro; 25.2 ± 7.3	P; G	P: NR G: 5v5 OG	28	NR	RPE (1–10)	sRPE	Quanter Mobile App (Kvantia, Helsinki, Finland)	Weekly load sRPE (including practice events) Pre-season: 2168 ± 911 First round: 1612 ± 881 Second round: 1750 ± 729
Senbel et al. (2021) [29] (NR; NR; NR)	P; G	FCS, RT, CT	NR	NR	RPE (1–10)	RPE; sRPE	NR	NR
Batalla-Gavalda et al. (2022) [56] (10; A; 21.3 ± 2.71)	P; G	P: FCS G: 5v5 OG	NR	P: NR G: 68	RPE (6–20)	RPE	RPE: 30′ after game and 10′ after practice. Reported individually in an isolated area	Data of 10 games (min; average; max) RPE: 15.2 ± 2.4; 16.8 ± 1.8; 18 ± 1.1
Willberg et al. (2022) [37] (37; Pro; 23.5 ± 4.1)	G	5v5 OG 3v3 OG	NR	NR	RPE (1–10)	RPE	RPE: 15–30′ after game	Team's average: 5v5 OG: 6 ± 2 3v3 OG: NR

NR: not reported; A: amateur; Y: youth; Pro: professional; E: elite; P: practice; G: game; SSG: small side game; 2v2: two versus two players; 4v4: four versus four players; 5v5: five versus five players; FC: full-court task; HC: half-court task; DT: defensive task; SG: simulated game conditions; WD: without defense; ST: superiority (offense) task; RT: resistance training; CT: conditioning tasks; TT: total time; UT: useful time; LTLS: low training load session; MLTS: moderate load training load session; HLTS: high load training session; RPE: rating perceived exertion (AU); sRPE: session-rating perceived exertion (AU); U(15,16,18): under age group; AU: arbitrary units.

Table 3. Internal load HR sensor-based.

Publication (n; Level; Age)	Event: Practice Game	Event: Study-Defined Practice Mode(s)	Observation: Obs. by Player	Observation: Total Statistical Units	Method	Metrics	Tool(s); SF; Body Place Worn	Outcome
Matthew et al. (2009) [52] (9; A; 25.8 ± 2.5)	G	5v5 OG	9	81	HR	% of time spent >85% HRMax; HRAvg	Polar S810 (Polar Electro Oy, Kempele, Finland); 15-s SF; NR	Mean 80.4% time at HR greater than 85% of HRMax (relative to total time) Mean 93.1% time at HR greater than 85% of HRMax (relative to live time) Mean 166.3 ± 9.4 HRAvg in 1st half and 163.3 ± 9.0 in 2nd half.
Narazaki et al. (2009) [19] (6; E; 20.0 ± 1.3)	G	5v5 OG	6	36	HR	HRPlay; HRRest	Polar watch (Polar Electro Oy, Kempele, Finland); NR SF; wrist	HRPlay (bpm): 168.7 ± 11.0 HRRest (bpm): 152.5 ± 11.5
Klusemann et al. (2012) [23] (8; Y; 17.4 ± 0.7)	P	SSG (2v2; 4v4)	19	152	HR	%HRMax, %HRAvg, % time spent in two different HR zones	Suunto Heart Rate sensor (Suunto™, Vantaa, Finland); NR; NR	Player's average by task format: 4v4; 2v2; HC; FC; 2 × 5 min; 4 × 2.5 min % HRMax: 92 ± 3; 92 ± 3; 92 ± 3; 92 ± 3; 92 ± 3; 92 ± 2 % HRAvg: 83 ± 5; 86 ± 4; 84 ± 5; 85 ± 4; 86 ± 4; 83 ± 3 % time in Z4: 51 ± 20; 55 ± 24; 46 ± 27; 56 ± 19; 53 ± 26; 58 ± 9 % time in Z5: 22 ± 25; 30 ± 31; 20 ± 27; 25 ± 27; 33 ± 32; 14 ± 13
Scanlan et al. (2012) [17] (10; A; 21.7 ± 3.65)	G	5v5 OG	8	NR	HR	HRAvg; %HRMax	Polar Team System (Polar Electro, Oy, Kempele, Finland); 5-s SF; NR	Team's average by quarters: HRAvg; %HRMax Q1: 165 ± 4; 83.2 ± 2.6 Q2: 163 ± 5; 84 ± 2.6 Q3: 161 ± 4; 81.3 ± 1.9 Q4: 162 ± 6; 81.5 ± 2.9 1st Half: 163 ± 3; 82.4 2nd Half: 161 ± 4; 81.2 ± 1.9 Match: 162 ± 3; 82.4 ± 1.3
Atli et al. (2013) [20] (12; Y; 15.5 ± 0.5)	P	HC, FCS	NR	NR	HR	HRAvg, %HRMax	Polar S810 HR (Polar Electro, Oy, Kempele, Finland); 5-s SF; NR	Player's average values by type of task: HC; FC HRAvg: 161.8 ± 6.2; 180.9 ± 5.7 %HRMax: 76.3 ± 2.5; 85.6 ± 3.1
Nunes et al. (2014) [58] (19; E; 26 ± 5)	P	FCS	NR	NR	HR	SHRZ	NR	Player's average: 255 ± 62
Abad et al. (2016) [24] (15; Y; 16.9 ± 1.1)	P; G	P: 5v5 SG G: 5v5 OG	1	15	HR	HRMax	Polar Team Pro (Polar, Kempele, Finland); NR; NR	Practice and game: HRmax: 195.27 ± 8.40
Vencúrik et al. (2016) [45] (10; Pro; 20.4 ± 2.8)	G	5v5 OG	1	10	HR	%HRMax, time spent in five different HR zones	Suunto Team Pack (Suunto Oy, Vantaa, Finland); 2-s SF; NR	Player's average by position (point guards; forwards; centers): %HRmax: 88.2 ± 3.5; 87.8 ± 3.1; 88.9 ± 3.4 Z3 (<85%): 24.0 ± 19.4; 24.3 ± 12.5; 19.8 ± 13 Z4 (85–95%): 63.7 ± 17.6; 67.9 ± 10.7; 65.9 ± 15.8 Z5 (>95%): 12.3 ± 13.9; 7.9 ± 10.8; 14.2 ± 16.2
Batalla et al. (2018) [55] (10; A; 21.3 ± 2.71)	G	5v5 OG	10	100	HR	%HRMax	Suunto Team Pack (Suunto Oy, Vantaa, Finland); NR; NR	%HRMax by quarters: Q1: 90.2 ± 4.4; Q2: 90.3 ± 4.2 Q3: 89.6 ± 3.4; Q4: 90.4 ± 2.5
Montgomery et al. (2018) [31] (208; E, Y; 22.9 ± 5.6)	G	3v3 OG	NR	635	HR	HRMax; HRAvg	Polar T34 (Polar, Kemple, Finland); NR; NR	HRMax: 198 ± 9 HRAvg: 165 ± 18

Table 3. *Cont.*

Publication (n; Level; Age)	Event		Observation		Method	Metrics	Tool(s); SF; Body Place Worn	Outcome
	Practice Game	Study-Defined Practice Mode(s)	Obs. by Player	Total Statistical Units				
Sanders et al. (2018) [35] (10; E; 19.8 ± 1.3)	G	5v5 OG	31	310	HR	HRMax; HRAvg; time spent in six different HR zones; SHRZ	Polar Team Pro (Polar, Kempele, Finland); NR; NR	Average by position (guards; forwards; centers): HRmax: 195.7 ± 6.7; 187.3 ± 8.8; 194.2 ± 8.8 HRavg: 146.0 ± 15.1; 149.9 ± 14.5; 151.1 ± 14.0 Z1 (50–60%): 4.3 ± 2.8; 3.0 ± 3.5; 3.6 ± 3.9 Z2 (60–70%): 3.2 ± 2.0; 3.4 ± 2.1; 4.7 ± 3.1 Z3 (70–76%): 1.4 ± 0.8; 2.1 ± 1.4; 2.6 ± 2.0 Z4 (77–84%): 1.9 ± 1.1; 3.5 ± 2.0; 2.5 ± 1.5 Z5 (85–100%): 9.2 ± 3.8; 10.0 ± 4.3; 8.4 ± 3.5 85% HRmax: 61.1; 69.2; 66.3 SHRZ: 68.3 ± 15.1; 80.1 ± 23.1; 72.9 ± 21.2
Lupo et al. (2019) [34] (15; E; 16.7 ± 0.5)	P	FCS	19	268	HR	SHRZ	Polar H7 (Polar Electro Oy, Kepele, Finland); 1-s SF; chest	Player's average by type of session: Strength: 229 ± 14.4 Conditioning: 229 ± 19 Technique: 162 ± 12.1
Reina et al. (2019) [49] (10; A; 21.7 ± 3.65)	P; G	P: SG G: 5v5 OG	47	155	HR	HRMax, HRAvg, %HRMax, time spent in six different HR zones	Garmin™; NR; NR	Team's average: HRMax: 175.18; HRAvg: 145.91; %HRMax: 72.95; Z1 (50–60%): 17.78; Z2 (60–70%): 19.32; Z3 (70–80%): 23.28; Z4 (80–90%): 27.38; Z5 (90–95%): 9.19; Z6 (>95%): 1.27 Average in games: Average team values HRMax: 192.33; HRAvg: 169.18; %HRMax: 84.59; Z1 (50–60%): 3.66; Z2 (60–70%): 6.30; Z3 (70–80%): 12.35; Z4 (80–90%): 37.14; Z5 (90–95%): 31.84; Z6 (>95%): 8.09
Reina et al. (2019) [30] (12; Y; U13)	P; G	P: NR G: 5v5 OG	35	420	HR	%HRAvg, %HRMax	Garmin™; NR; NR	NR
Sanders et al. (2019) [35] (13; E, Y; 19.6 ± 1.3)	P; G	P: NR G: 5v5 OG	NR	NR	HR	HR, SHRZ	Polar Team Pro (Polar, Kempele, Finland); 1-s SF; chest	Showed data including practice and game average Average values for groups (large; moderate; minimal): HRmax: 196.5 ± 1.4; 195.5 ± 1.8; 193.2 ± 1.6 HRavg: 132.6 ± 1.1; 130.8 ± 1.0; 127.9 ± 1.6 SHRZ: 352.2 ± 11.6; 314.5 ± 13.4; 276.5 ± 13.2 Time >85% HRmax (min): 21.6 ± 1.2; 20.0 ± 1.4; 16.4 ± 1.6
Vala et al. (2019) [46] (17; Pro; 23.4 ± 2.1)	G	5v5 OG	NR	16	HR	HRAvg, %HRMax; time spent in five different HR zones	Polar Team System 2 (Polar, Kemple, Finland); NR; NR	HRAvg by league and position: 1st league; 2nd league Guards: 174.8 ± 9.2; 183.3 ± 6.7 Forwards: 182.9 ± 12.3; 169.7 ± 6.7 Centers: 190.6 ± 11.3; 174.4 ± 9.1 Total: 183.2 ± 12.8; 176.1 ± 10.3 Average % HRmax by league and position: 1st league; 2nd league Guards: 91.1 ± 5.6; 90.1 ± 4.4 Forwards: 92.3 ± 5.6; 85.7 ± 3.4 Centers: 92.2 ± 4.8; 90.3 ± 2.9 Total: 91.9 ± 5.3; 88.8 ± 4.2 % time spent by positions: guards; forwards; centers Z1 (<80%): 0.64; 0.00; 0.00 Z2 (80–85%): 7.40; 3.67; 3.90 Z3 (85–90%): 42.41; 27.34; 17.36 Z4 (90–95%): 40.42; 45.5; 57.82 Z5 (>95%): 9.13; 23.49; 20.93

Table 3. *Cont.*

Publication (n; Level; Age)	Event		Observation		Method	Metrics	Tool(s); SF; Body Place Worn	Outcome
	Practice Game	Study-Defined Practice Mode(s)	Obs. by Player	Total Statistical Units				
Kraft et al. (2020) [50] (NR; NR; NR)	P	NR	NR	124	HR	HR	Polar H7 sensor and Polar Team System (Polar, Kemple, Finland); NR; NR	Player's average values: SHRZ: 313 ± 112
Lukonaitene et al. (2020) [26] (24; E, Y; 18.8 ± 0.7)	P; G	P: FCS G: 5v5 FG	33	792	HR	TRIMPB	H10 Polar Sensor (Polar, Kemple, Finland); NR; NR	Team's average U20: 214.60 ± 109.42 U18: 304.95 ± 171.83 Showed data including practice and game
Suárez-Iglesias et al. (2020) [28] (10; Pro; 18.6 ± 3.5)	P	1v1; DT	12	120	HR	%HRMax; %HRAvg; %Time spent 80–89% HRMax; %Time spent 90–100% HRMax; SHRZ	Suunto Team Pack (Suunto Oy, Vantaa, Finland); 5-s SF; NR	Team's average by tasks (1v1; defense): %HRMax: 93.3 ± 4.9; 94.1 ± 5.6 %HRAvg: 83.6 ± 6.3; 85.1 ± 6.5 %Time spent at 80–89% HRMax: 43.7 ± 20.2; 40. ± 23.8 %Time spent at 90–100% HRMax: 25.7 ± 29.3; 45.2 ± 31.7 SHRZ: 3.8 ± 0.6; 4.3 ± 0.5
Adrianova et al. (2021) [61] (10; Pro; 23 ± 3)	G	5v5 OG	89	NR	HR	HRMax, HRAvg, number of kcal	Polar Team System HR sensors H10 (Polar, Kemple, Finland); NR; NR	Player's average by season: season 2018/19; season 2019/20 HRMax: 197; 187 HRAvg: 137.7; 140.3 Total kcal: 875.7; 972.6 Kcal/min: 41.6; 46.9
Brini et al. (2021) [44] (12; Pro; 24.8 ± 1.8)	P	SSG	NR	NR	HR	HRAvg	Polar Team System (Polar, Kemple, Finland); 5-s SF; NR	HRAvg: 187.1.7
Espasa-Labrador et al. (2021) [4] (13; E, Y; 16.3 ± 1)	P	FCS	35	164	HR	SHRZ; TRIMP;	Polar Team Pro System (Polar, Kemple, Finland); 200Hz SF; chest	Player's average during session: SHRZ: 276.1 ± 61.9 TRIMPB: 61.7 ± 10.1
Piñar et al. (2021) [47] (13; Pro; 25.2 ± 7.3)	P; G	P: NR G: 5v5 OG	28	NR	HR	NR	M400 Polar (Polar, Kemple, Finland); NR; NR	NR
Vencúrik et al. (2021) [32] (18; Y, Pro; 18.8 ± 1.9)	P; G	P: NR G: 5v5 OG	14	122	HR	% of time spend in three different HR zones	Suunto Team; Pack telemetry system (Suunto Oy, Vantaa, Finland); 2-s; NR	NR
Batalla-Gavalda et al. (2022) [56] (10; A; 21.3 ± 2.71)	P; G	P: FCS G: 5v5 OG	NR	P: NR G: 68	HR	HRAvg	Suunto Team Pack (Suunto Oy, Vantaa, Finland); NR; NR	Player's average during 10 games: HRMin: 125.2 ± 10.9 HRAvg: 140.4 ± 11.1 HRMax: 147.3 ± 10.6

Table 3. *Cont.*

Publication (n; Level; Age)	Event: Practice Game	Event: Study-Defined Practice Mode(s)	Observation: Obs. by Player	Observation: Total Statistical Units	Method	Metrics	Tool(s); SF; Body Place Worn	Outcome
Gutiérrez-Vargas et al. (2022) [33] (32; E, Y; 16.2 ± 1)	G	5v5 OG	NR	NR	HR	HRMax, % time spent in five different HR zones	Garmin™; NR; NR	Average values by position: team; guards; forwards; centers Winning game: HRMax: 188.3 ± 17.3; 188 ± 23.6; 188 ± 17.7; 189 ± 10.6 50–60% HR: 6.7 ± 14.1; 6 ± 16; ±7 ± 13.8 60–70% HR: 9.1 ± 11.3; 12.8 ± 13.2; 6.4 ± 7.5; 8.1 ± 13.1 70–80% HR: 15.8 ± 13.6; 21 ± 17.9; 16.5 ± 14.2; 10 ± 8.7 80–90% HR: 30.9 ± 17.8; 32 ± 21.2; 31.5 ± 15.9; 21.1 ± 16.4 >90% HR: 21.2 ± 15.9; 16.4 ± 17.4; 24.2 ± 15.5; 28.9 ± 14.9 Losing game: HRMax: 189.2 ± 16.2; 189.5 ± 20.7; 188.7 ± 14; 189.6 ± 16.1; 50–60% HR: 8.4 ± 19.2; 12.2 ± 22.6; 7.5 ± 19.0; 5.6 ± 16.1; 60–70% HR: 8.25 ± 12.4; 8.2 ± 10.6; 7.4 ± 9.2; 9.1 ± 17.2; 70–80% HR: 11.9 ± 10.5; 12.1 ± 10.7; 13.9 ± 11.9; 9.8 ± 9; 80–90% HR: 29.9 ± 17.8; 29.3 ± 17.3; 32.1 ± 17.7; 28.1 ± 18.5 >90% HR: 24.4 ± 16; 22.4 ± 15.5; 23.7 ± 16.2; 27 ± 16.3
Willberg et al. (2022) [37] (37; Pro; 23.5 ± 4.1)	G	5v5 OG 3v3 OG	NR	NR	HR	HR_{Max}, HR_{Avg}, time spent in eight different HR zones	Vector Elite Vest (Catapult Sports, Melbourne, Australia); 10 Hz; Upper body	Team's average by type of competition: HRAvg; Dominant HR Zone 5v5 OG: 6 ± 2; 151.4 ± 22.7; 160–180 (zone 7) 3v3 OG: NR; 160.8 ± 16.1; 160–180 (zone 7)

NR: not reported; A: amateur; E: elite; Y: youth; Pro: professional; G: game; P: practice; 5v5: five versus five players; 4v4: four versus four players; 3v3: three versus three players; 2v2: two versus two players; 1v1: two versus two players; SSG: small side game; FC: full-court task; HC: half-court task; ST: superiority (offense) task; WD: without defense; DT: defensive task; SG: simulated game conditions; HR: heart rate (beats per minute); $HR_{Max:}$ maximal heart rate (beats per minute); HR_{Avg}: average heart rate (beats per minute); HR_{Min}: minimal heart rate (beats per minute); HR_{Play}: heart rate playing (beats per minute); HR_{Rest}: heart rate resting (beats per minute); >85%HR_{Max}: time spent over 85% of individual maximal heart rate; SHRZ: summated heart rate zones; $TRIMP_B$: Banister's training impulses; U(13,18,20): under age group; SF: sampling frequency; Z1: time spent in zone 1 of heart rate; Z2: time spent in zone 2 of heart rate; Z3: time spent in zone 3 of heart rate; Z4: time spent in zone 4 of heart rate; Z5: time spent in zone 5 of heart rate; Z6: time spent in zone 6 of heart rate; kcal: kilo calories; Q1: 1st quarter; Q2: 2nd quarter; Q3: 3rdquarter; Q4: 4th quarter; AU: arbitrary units.

Table 4. Other devices used to monitor the load.

Publication (n; Level; Age)	Event		Observation		Method	Metrics	Tool(s); Characteristics	Outcome
	Practice Game	Study-Defined Practice Mode(s)	Obs. by Player	Total Statistical Units				
Matthew et al. (2009) [52] (9; A; 25.8 ± 2.5)	G	5v5 OG	9	81	BLC	mmol·L^{-1}	Analox LM5 (Analox Instruments Ltd., London, UK)	Player's average: 1st Half: 5.4 ± 1.5; 2nd Half: 5.0 ± 1.4 Game: 5.2 ± 2.7 (55.9% of maximum)
Narazaki et al. (2009) [19] (6; E; 20.0 ± 1.3)	G	5v5 OG	6	36	BLC; VO_2	mmol·L^{-1}; ml/Kg/min, %VO_{2Max}	NR, Portable VO2000 (Medical Graphics Corp., St. Paul, MN, USA); VO_2: 0.05 Hz	Player's average: BLC_{Play}: 3.2 ± 0.9 VO_{2Play} (ml/Kg/min): 33.4 ± 4.0 VO_{2Play} (%VO_{2Max}): 66.7 ± 7.5 VO_{2Rest} (ml/Kg/min): 21.3 ± 2.1 VO_{2Rest} (%VO_{2Max}): 42.7 ± 6.1
Scanlan et al. (2012) [17] (10; A; 21.7 ± 3.65)	G	5v5 OG	8	NR	BLC	mmol·L^{-1}	Accusport Lactate Analyser (Boehringer, Mannheim, Germany)	Team's average by different periods: Q1: 3.6 ± 0.7; Q2: 4.6 ± 2.4; Q3: 3.4 ± 0.6; Q4: 3.5 ± 1.2 1st Half: 4.1 ± 1.7; 2nd Half: 3.4 ± 1.0 Game: 3.7 ± 1.4
Montgomery et al. (2018) [31] (208; E, Y; 22.9 ± 5.6)	G	3v3 OG	NR	635	BLC	mmol·L^{-1}	Lactate Scout+ (SensLab GmbH, Germany)	Player's average by competition: WCh: 5.98 ± 0.98 ECh: 5.55 ± 0.50 U18: 5.69 ± 0.62
Brini et al. (2021) [44] (12; Pro; 24.8 ± 1.8)	P	SSG	NR	NR	BLC	mmol·L^{-1}	3 min after practice. Lactate Pro, Arkray, Japan	NR

NR: not reported; A: amateur; E: elite; Y: youth; Pro: professional; P: practice; G: game; 5v5: five versus five players; 3v3: five versus five players; SSG: small side game; BLC: blood lactate concentration; VO_2: oxygen consumption; VO_{2Max}: maximal oxygen consumption; WCh: World Championship; ECh: European Championship; U18: under 18 years old.

4. Discussion

The main finding of this systematic review was the quantification of internal load in female basketball players, which was most commonly achieved using methods based on RPE and HR metrics. These measures were then incorporated into various equations to evaluate the physiological response to activity. Some publications also incorporated the use of BLC and VO_2 measurements. However, the use of multiple metrics to quantify physiological responses, often with little standardization, led to significant heterogeneity among the studies. This heterogeneity may limit the ability to draw meaningful comparisons between the studies. This review provides a reference framework that highlights the methods and metrics used in current research on female basketball by comparing the extracted data obtained in all included works. The most relevant findings are discussed in detail below.

4.1. Subjective Methods for Internal Load Monitoring

The RPE has emerged as a widely used method for load monitoring in several team sports [5], including basketball [7]. This method has two major advantages over other techniques: it is (1) cost-effectiveness and (2) non-invasive. Such advantages address two common challenges experienced by many women's basketball teams, namely the restrictions prohibiting players from using sensors during matches and the limited financial resources to access sensor-based monitoring techniques. As a result, RPE has been frequently employed in studies evaluating internal load during basketball matches, as evidenced in this systematic review (14/29 of publications reporting its use).

Although the RPE method offers benefits, it also poses certain limitations. Despite the fact that most of the studies referenced Borg's (1970) work to justify the scale employed [63], few studies addressed the methodological aspects associated with the RPE method. Halperin et al. (2019) underscore that the method requires (1) identifying the construct intended to be obtained from the response (fatigue, discomfort, or intensity/hardness), (2) establishing the temporal range evaluated by the athlete (full session or specific tasks), (3) providing researchers and athletes with instructions (precise question, timing, verbal communication, etc.) and employing an appropriate scale (qualitative visual or quantitative verbal: between 0–10, 6–20, etc.), and (4) evaluating the entire body or specific parts [64]. These methodological aspects may account for the heterogeneity of the data found, particularly in the assessment of practice. Moreover, the athletes' experience with the method must also be considered. This need for familiarization is evident when observing data in young athletes (U15 and U16), who report the lowest training values (2.9–3.1 AU) [27]. All the above-described aspects modify the athlete's response, and few studies detailed them in their methods section. Some authors note the time elapsed between the end of the event and the question, which ranges from 0 to 30 min [37,44,56], the instrument employed to gather responses (paper and pen, a computer, or mobile applications), and whether the assessment was conducted individually and in a designated area. These methodological processes, albeit good, may be insufficient, and thoughtful consideration of the aforementioned aspects is crucial for appropriate load monitoring and management.

In addition to the limitations of RPE that we noted above, a recent systematic review with meta-analysis examined the subjective perception of effort in female athletes throughout the menstrual cycle [65]. Although the authors found that hormonal variations throughout the different phases of the menstrual cycle could affect certain evaluated items, such as motivation, competitiveness, sleep, muscle soreness, and fatigue, RPE did not significantly vary. As a result, the authors suggested that there may be methodological limitations in the use of RPE. These results highlight the need to be cautious when using subjective methods to study female basketball players, especially given the physiological differences from male players. It is necessary to conduct further studies on how hormonal levels may modify the perceived effort. Researchers and coaches must consider the physiological characteristics specific to female athletes when studying load through psychophysiological methods.

In addition to the limitations of RPE already noted, Foster's method faces yet another limitation [66]. While this method is useful for quantifying internal load in practice, it becomes less reliable when applied to competitive events where the exposure time is shorter relative to training events. This can make it difficult to compare or mix load values between practice and games. For example, a 100-min practice session where a player reports an RPE of 5 (500 arbitrary units) will be higher than 40 min at an RPE of 10 (400 arbitrary units). To our knowledge, no solutions have been proposed to solve this aspect specific to basketball. To address this issue, one possibility could be to weigh the competition's load values by a factor based on the characteristics of the population of interest. Further research is needed to fully understand and address this issue in basketball load monitoring.

4.2. Device-Based Methods for Internal Load Monitoring

As previously noted, limitations exist with respect to equipping basketball players with sensors during official matches, which could impede the study of their physiological responses. This could explain why we find more publications in young and amateur female players, where there may be less control over the use of these devices. Despite this, studies have been conducted evaluating the cardiac responses in professional and elite female players, indicating that there may be a relationship between a higher competitive level and increased internal response. This could be an indicator that physical demand is also higher. This relationship has already been described in the literature in many team sports, including women's basketball [4,9].

HR monitoring is a widely adopted technique in team sports for evaluating the intensity, volume, and density of work [4,67]. However, its applicability to basketball may have the same limitations as other team sports [68]. The limitations of HR monitoring include the lag between neuromuscular activity and cardiovascular response and the requirement for extended exertion to produce significant cardiovascular activity. So, one optimal use of HR sensors is assessing the density of effort (ratio between activity and rest) in either a particular task or an entire training session [68]. Moreover, cardiac reaction to stress is an individualized parameter, and comparing individuals to averaged data could result in the misinterpretation of individual physiological responses. To avoid such errors, an individualized approach to monitoring should be adopted, considering the individual's complete participation in different training tasks or competitions, avoiding mainly team sums and averages, including metrics relative to the individual maximum HR, such as $\%HR_{Max}$, $\%HR_{Avg}$, or the time spent in different zones. Notably, the included studies in this systematic review failed to explain how the HR_{Max} of the players was estimated.

These limitations of HR data in team sports could have a relevant impact when generating new indicators based on cardiac activity records. Examples of these new indicators are the $TRIMP_B$ and the SHRZ [68]. The latter method could be a suitable alternative in the context of women's basketball, as it weights the time spent by players in higher heart rate zones with a higher constant. Therefore, one minute at 150 bpm is not the same as one minute at 190 bpm. However, the question of how many HR zones is appropriate must be resolved. While the original Edwards' SHRZ method proposed five thresholds (zone 1: 50–60%, zone 2: 60–70%, zone 3: 70–80%, zone 4: 80–90%, zone 5: >90%), in this systematic review, we have identified publications that use a different number of thresholds and, therefore, different percentages of HR (Table 3). One of the proposals was made by Reina et al. in 2019 [49] through six different zones. The interest of this division lies in dividing Edwards' original zone 5 into 2: (1) zone 5: 90–95%, (2) zone 6: >95%. This would allow for discrimination if a player reaches values close to their maximum, since observing this requires sustained effort over time at a very high intensity. This relationship between external load and cardiac response has been described in basketball and other sports [4,9]. This hypothesis gains further support by examining the differences in the time spent by players in zone 6 (>95% HR_{Max}) between 3v3 and 5v5 basketball formats. In the 3v3 format, which has a shorter game duration, fewer participants, more space, and fewer interruptions due to different foul and serve regulations [69], players spent approximately

85% of their time in zone 6. On the other hand, in the 5v5 format, which has a longer game duration, more players, less space, and more interruptions, the time spent in zone 6 did not even reach 10% [62]. These findings suggest that the demands of the game format influence the intensity and distribution of the players' efforts during the game.

Finally, some authors indicate the importance of evaluating time-related cardiac responses to gain a more accurate understanding of the heart's response to the time dose duration [49]. Such an approach may provide more precise insights into the physiological demands related to external load. The utilization of the useful time metric, as a quantification of effort, is most frequently applied in competitive settings, as discussed above about Foster's method. In addition, in the case of official competitions, this systematic review found that players spent most of the time above 85% of their HR_{Max} [45,52,62]. However, extending the use of useful time to training sessions, and even isolated tasks, could offer significant insights. Such an approach could help to identify the intensity and distribution of effort during training. Furthermore, these data may inform the development of more effective training programs, helping coaches to optimize and improve the physical performance of female basketball players by targeting specific respiratory, metabolic, and/or neuromuscular aspects. Future research and consensus may resolve these limitations in the use of heart rate, providing specific knowledge related to the characteristics of women basketball players.

4.3. Other Device-Based Methods Used for Internal Load Monitoring

Our systematic review identified two additional methods for monitoring internal load in basketball players during training and competition: BLC and VO_2 analysis. Although the number of publications was limited, these methods offer valuable insights into the physiological responses of athletes. However, they are also invasive and require specific expertise and equipment for their accurate application, including blood handling, instrument calibration, and exercise breaks. Nonetheless, these methods could provide valuable information for the precision training and performance optimization of basketball players.

The BLC confirms the energy system used, specifically the process of glycolysis. This byproduct of cellular activity has been used to understand muscle demand and fatigue [52]. The values obtained from competition show a range between 3.2–6.0 mmol·L^{-1}, including 5v5 and 3v3 competitions. These values were similar to those found in male basketball players [11]. The observed range of lactate concentration during competition suggests that glycolysis is a significant contributor to energy production. This could be explained by the specific demands of basketball, such as repeated high-intensity actions and intermittent efforts. Although one included publication studied the effects of small-sided games in training [44], it did not report absolute lactate values, and therefore no reference values were obtained for these events. It could be speculated that the BLC values in training could be lower due to a lower density compared to competition. Therefore, this method might be better suited for specific tasks than for whole sessions.

BLC monitoring in basketball may provide valuable information about energy metabolism and muscle demand. The potential invasiveness of this method for monitoring internal load may discourage its use in some contexts. However, it may be possible to overcome these barriers as technology progresses. Compact, secure, and real-time monitoring sensors have been reported in the literature [70], which could offer a promising alternative for internal load monitoring. These advancements could facilitate the use of these metrics in decision-making processes in various settings. For this reason, more research is needed on the effects of training and competition on these types of metabolic markers, which will help us to better understand subsequent adaptation.

Finally, our systematic review identified few studies reporting VO_2 in female basketball players, with only one study reporting values during games [35]. The reported values of 33.4 ± 4.0 mL/kg/min (66.7 ± 7.5% VO_{2Max}) suggest moderate to high aerobic demands during competition, which could be important for designing effective training programs for female basketball players. Further research in this area is needed to fully understand the metabolic demands of women's basketball.

4.4. Limitations

The variability in metrics used for internal load assessment in female basketball makes it challenging to compare results within and between events, competitive levels, and age groups. This issue has been identified in previous systematic reviews [7,14]. A potential explanation for the diverse metrics and values reported in the literature could be the publication of retrospective studies that lack a clearly defined methodology for data collection. As a result, the values obtained may not reflect the actual training dynamics. Many of the studies included in this review did not provide essential information on the dose of training or competition, research methodology, or data and participant loss during the process. To enhance the comprehensiveness of future research, it is recommended to include external load as a contextual factor when analyzing physiological responses.

5. Conclusions

This systematic review provides an overview of the methods and metrics used to measure internal load in female basketball players during both practice and competition. We identified the most commonly used approaches and highlighted the advantages and limitations of each. The findings suggest that future research in this area should prioritize the standardization of metrics and the development of objective, non-invasive measures of internal load. Additionally, coaches and practitioners should be aware of the limitations of subjective methods, such as RPE, and consider using multiple metrics to gain a more comprehensive understanding of internal load in female basketball players. Although this review provides a valuable reference framework for researchers and practitioners in this field, the use of multiple metrics with little standardization led to significant heterogeneity among the studies. Future research could address this limitation by adopting more consistent measurement protocols and standardizing the use of metrics. Overall, this review highlights the importance of accurately measuring internal load in female basketball players and provides a roadmap for future research in this area. Further research is needed to develop more objective measures of internal load and determine the optimal balance between external and internal load for improving athletic performance and preventing injury in this population.

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Publicación III

Relationship between internal and external load in elite female youth basketball players

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ORIGINAL ARTICLE

Relationship between internal and external load in elite female youth basketball players

Javier Espasa Labrador[a,b], **Javier Peña**[c,d,*], **Toni Caparrós Pons**[a,d], **Michael Cook**[e], **Azahara Fort Vanmeerhaeghe**[f,g,h]

[a] *National Institute of Physical Education of Catalonia, University of Barcelona, Barcelona, Spain*
[b] *School of Health Sciences, TecnoCampus-Mataró, University of Pompeu Fabra, Barcelona, Spain*
[c] *Sport and Physical Activity Studies Centre (CEEAF), University of Vic-Central University of Catalonia (UVic-UCC), Barcelona, Spain*
[d] *Sport Performance Analysis Research Group, University of Vic-Central University of Catalonia (UVic-UCC), Barcelona, Spain*
[e] *Sport Performance Centre, Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Alberta, Canada*
[f] *Faculty of Psychology, Education and Sports Blanquerna, University of Ramon Llull, Barcelona, Spain*
[g] *Department of Sports Sciences, Ramon Llull University, FPCEE and FCS Blanquerna, Barcelona, Spain*
[h] *Segle XXI Female Basketball Team, Catalan Federation of Basketball, Barcelona, Spain*

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Abstract

Introduction: Monitoring load has been a key point in team sports during last years. This study aimed to determine the relationship between the external and internal training load during full basketball practices in elite female youth basketball players.

Material and methods: Thirteen elite female youth basketball players (age 16.3±1 years, height 181.7±5.8cm and body mass 71.2±9.6kg) had physical and physiological monitored over seven weeks. Players' internal load was assessed using the session-rating of perceived exertion (sRPE), the Edward's summated heart rate zones model (SHRZ) and, the Banister's training impulse ($TRIMP_B$). The external load was determined through: 1) total accelerations (TA); the sum of all accelerations and decelerations; 2) maximal accelerations and decelerations (TAMax); 3) total accelerations per minutes ($TA \cdot min^{-1}$); 4) accelerations per minute ($Acc \cdot min^{-1}$); and 5) decelerations per minute ($Dec \cdot min^{-1}$). Heart rate-based and accelerometry models were assessed via Polar Pro technology.

Results: Correlations between variables revealed different magnitudes. SHRZ model showed a positive correlation with TA (0.63); the $TRIMP_B$ model showed a high degree of correlation with TA (0.78); the sRPE model also presented a high correlation with TA (0.62).

* Corresponding author at: Sport Performance Analysis Research Group, University of Vic-Central University of Catalonia (UVic-UCC), Barcelona, Spain.
E-mail address: javier.pena@uvic.cat (J. Peña).

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Conclusion: Our study establishes different levels of association between external and internal load models in elite female youth basketball players. However, we cannot assume that a high relationship between internal and external loads exists, as both models should be considered as different constructs.

Introduction

Today, technology allows monitoring and to describe sport demands with greater precision than ever before.[1–3] During the last decade, the physical demands of basketball have been described through several studies[4–6]; however, not many of them are explicitly related to female youth athletes. The development of smaller and more reliable devices has opened a new field of research in sports sciences, including new perspectives on the study of the physical demands and physiological responses of team sports, and specifically, within basketball contexts.[4,7–9] Recent studies using technology have described basketball as a high demanding sport considering its aerobic and anaerobic requirements, its changes of direction, accelerations, decelerations, jumps, sprints, contacts and, specific skills. Thus, performance in elite basketball competition is closely related to the players' fitness level.[7] Additionally, basketball imposes significant cognitive demands surrounding decision-making and anticipatory processes.[10] The measurement of the specific physical sport demands and the athlete's physiological responses, using different models, allows coaches and practitioners to obtain objective information about individual and collective training loads. The advances in the field of load monitoring are helping researchers and staff to optimize the sport-specific practices to raise player's fitness, promote specific adaptations, decrease the possibility of getting injured or experience non-functional overreaching, and overtraining syndrome or undertraining.[7,8,11,12]

Various models to monitor training loads in team sports exist, but the validity of these and their competitive development has important limitations. Thus far, to quantify sport demands and athletes' responses, two different categories of load units have been utilized. External load (EL) is defined as the dose of external stimulus applied to the athlete during practices or competitions.[12] In recent years, the use of global positioning systems (GPS) has become a reference method to measure EL in various field sports. However, its signal interference and imprecision in indoor sports has caused the development of local positioning systems (LPS), which are based in radiofrequency and the commercialization of devices incorporating accelerometers, gyroscopes, and magnetometers. Not many previous publications have monitored these physical demands through absolute or relative (min^{-1}) EL variables e.g., using Player Load (PL).[7,13,14] However, we can find several studies where the authors use secondary parameters derived from accelerometry, like speeds in the distances traveled[15].

On the other hand, internal load (IL) is an individual response to an external stimulus, resulting in physiological and psychological stress responding to the requirements imposed on the athlete. IL can be monitored through different metrics[12] such as 1) heart rate (HR), 2) oxygen uptake (VO_2), 3) biochemical indicators, 4) rating of perceived exertion (RPE), and 5) questionnaires. We can also find within the literature, different indices[16]: 1) Banister's training impulse ($TRIMP_B$)[17]; 2) session-RPE (sRPE)[18]; 3) Edward's summated heart rate zones model (SHRZ)[19].

The models mentioned above may allow a better understanding of the specific demands of basketball and individual acute and chronic changes. Variations in acute and chronic loads are the result of the athlete's cumulative IL during the training process. The IL of each player will be affected by physical demands so that higher EL values could involve increased energy costs during and after the activity. Understanding this relationship could allow a precise periodization of team and athlete activity during the season, lengthening their sports careers, following the dose-response paradigm in sports training. For this reason, we find some studies examining this association in team sports.[20,21] However, to the best of our knowledge, only one study has investigated the relationship between these models in adult basketball players[8]. However, no pieces of research looking for this association in female youth basketball players can be found.

To understand the relationship between internal and external loads could be a possible solution to improve the training and rehabilitation processes and managing more effectively the exposure minutes. Therefore, the main aim of this study was to determine the relationship between internal and external loads during basketball practices in elite female youth basketball players.

Material and methods

Design

This study followed a longitudinal descriptive research design. Training loads data were collected during a seven-week in-season period (February-April) of the 2016-17 Second Division competition of the Spanish professional basketball league (LF2). Each player contributed with a mean (±SD) of 13.67±5.96 sessions. For the analysis, the inclusion criteria were: (1) to complete the basketball team-training session; and (2) to collect all the variables of the session (minutes, heart rate, sRPE, and accelerometry). Load data were collected across 35 sessions, with a total of 164 registered events.

Player internal and external load values were collected across all the basketball training sessions. Two indicators of internal load were used: HR and sRPE. Besides, the external load was calculated using players' accelerometer outputs that were measured during practices. All training sessions were indoor in similar environmental conditions.

Participants

Thirteen elite female youth basketball players (age 16 ± 1 years, height 181 ± 6 cm and body mass 71 ± 9 kg, and 7± 1 years of playing experience), participating in a basketball national player development program, volunteered for this study, and were monitored across the first seven weeks of the season (26.9% of the weeks belonging to the competitive period). All of the participants competed in the Second Division of the Spanish professional basketball league (LF2).

Before starting the study, the health of all the participants was checked by the team's physicians. Participants and their legal guardians received detailed written and verbal information about the possible risks and discomforts associated with the testing procedures. Written informed consent was obtained from all the participants and their legal guardians, respectively. Procedures performed in the study followed the Declaration of Helsinki (World Medical Association, 1964) and its later amendments.[22]

Methodology

Internal and external loads were assessed via Polar Pro technology (Polar Team Pro, Polar Electro Oy, Finland). These devices incorporated HR and acceleration sensors with a sampling frequency of 200 Hz. Only accelerations maintained at least 0.5 seconds were included in the analysis. Sensors were placed in the middle of the player's chest. The devices were assigned to the same athlete throughout the duration of the whole study. Following similar protocols, RPE was collected 30 minutes after each practice.

Before initiating the study, all players were familiarized with the devices and the procedures to report RPE. Additionally, before starting the data collection process, individual HR_{max} and basal heart rate (HR_{basal}) were calculated using a single test using the 30-15 Intermittent Fitness Test[23] and measuring their resting heart rate for 5 minutes after waking up during 10 minutes. Before starting every basketball-specific session, players carried out a standardized warm-up with a duration of 10 min (Figs. 1 and 2).

The internal load was determined through player HR applied to $TRIMP_B$[17] and SHRZ[19] and individual rate of perceived exertion using sRPE.[18] Outcomes of all models are expressed in arbitrary units (AU).

The $TRIMP_B$ model calculates the load through individual player HR_{max}, HR_{basal}, and HR_{mean} during practice. The applied formula was the following:

$$TRIMP_B(AU) = [\text{Duration (min)} \cdot (HR_{mean} - HR_{basal})]/\left[(HR_{max} - HR_{basal}) \cdot 0,64e^{1,92x}\right]$$

Where, e = 2,712; x = $(HR_{mean} - HR_{basal})] / [(HR_{max} - HR_{basal})$.

SHRZ was calculated using HR based on Edwards's model.[19] This model assumes as individual IL the sum of the time spent in arbitrary HR-zones weighted multiplying the accumulated time in each HR zone (in minutes) by a relative factor for each zone:

$$SHRZ = (\textit{time} \text{ in zone } 1 * 1) + (\text{time in zone } 2 * 2) + (\text{time in zo}^{24}\text{ne } 3 * 3) + (\text{time in zone } 4 * 4) + (\text{time in zone } 5 * 5).$$

Where, zone 1 = 50-59% HR_{max}; zone 2 = 60-69% HR_{max}; Zone 3 = 70-79% HR_{max}; Zone 4 = 80-89% HR_{max}; and Zone 5 = >90% HR_{max}.

Each player reported their RPE individually to the researchers using the category ratio scale (CR-10) by answering the question, "How hard was the practice?" 30 min after the end of each training session.[18] This value was collected using a mobile app Quanter (Kvantia, Helsinki, Finland). This method shows a good fit in HR models when compared with paper-pencil methods sRPE was obtained by multiplying the duration of each session (in minutes) by the RPE of each player.[24]

$$sRPE = \text{RPE x Duration}$$

Where RPE = Borg's 1-10 category ratio scale.

Before starting the study, all players familiarized themselves with the RPE scale for four weeks. This model has been used consistently to monitor the psychophysiological loads in basketball.[6,25]

Outcomes selected to quantify EL were categorized into absolute and relative to time measurements. Absolute metrics were: 1) total accelerations and decelerations (TA) and

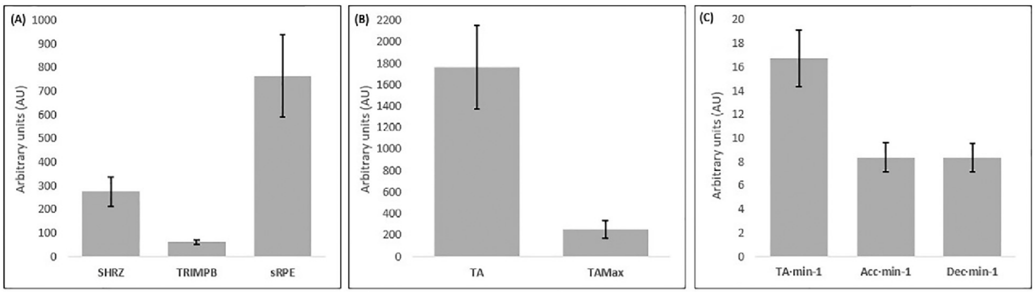

Fig. 1 The mean ± SD (A) individual absolute physiological responses values during practice; (B) absolute individual physical demand values during practice; and (C) relative to time external load during basketball practice (n = 164). SHRZ Score = Edward's summated heart rate zones model; $TRIMP_B$ = Banister's training impulse; sRPE = session-rating of perceived exertion; Total Accelerations = total accelerations and decelerations during practice; TAMax = sum of all maximal accelerations and decelerations; $TA \cdot min^{-1}$ = total accelerations per minute; $Acc \cdot min^{-1}$ = accelerations per minute; $Dec \cdot min^{-1}$ = decelerations per minute.

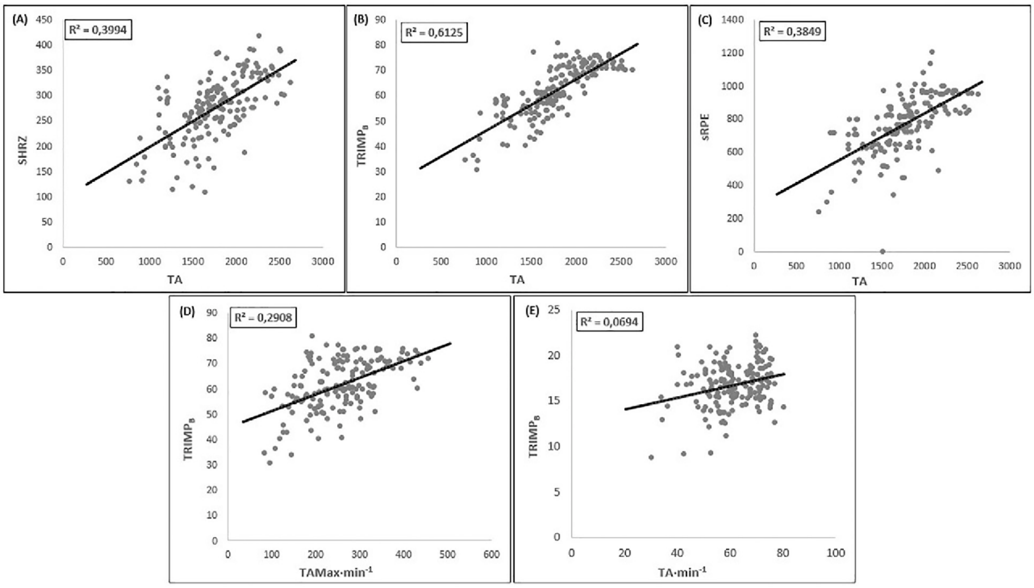

Fig. 2 Correlations between external and internal load during practice: (A) between TA and SHRZ; (B) between TA and TRIMP$_B$; (C) between TA and sRPE; (D) between TAMax·min^{-1} and TRIMP$_B$; (E) between TAMax·min^{-1} and TRIMP$_B$. (n = 164). 95% CI = 95% confidence intervals. R^2 = coefficient of determination.

2) the sum of all maximal accelerations and decelerations (TAmax; >2.0 m/s^2 + <-2.0 m/s^2). These acceleration thresholds are similar to those used in previous male basketball research.[26] The relative to time variables used were: 1) total accelerations per minute (TA·min^{-1}); 2) accelerations per minute (Acc·min^{-1}); 3) decelerations per minute (Dec·min^{-1}).

Statistical analyses

Due to the data sample size (n=164), the Kolmogorov-Smirnov test was used to examine if variables were normally distributed. As normality of the dataset was assumed, relationships between the internal and external load models were determined using Pearson's Rho product-moment correlation with 95% confidence intervals. Correlation magnitudes were defined according to the Hopkins's criteria[27] trivial: 0-0.09; low: 0.10-0.29; moderate: 0.30-0.49; large: 0.50-0.69; very large: 0.70-0.89; nearly perfect 0.90-0.99; 1 perfect. The significance level was set at $p \leq 0.001$. The coefficient of determination (R^2) was determined to understand the adjustment between the control models of the external and internal load. Means (±SD) were calculated for all descriptive and outcome measures. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS, version 21 for macOS, SPSS Inc, Chicago, IL).

Results

The mean ± SD external (TA, TA$_{max}$, TA·min^{-1}, Acc·min^{-1} and, Dec·min^{-1}) and internal (TRIMP$_B$, SHRZ, and sRPE models) loads of the basketball training events are shown in Table 1. The level of correlations and coefficients of determination between external and internal load models during basketball practices from this research study is shown in Table 1. We observed different correlation magnitudes between the internal and external models described in this research. A very large relationship was found between TA and TRIMP$_B$ model (0.78) and a large correlation between TA and SHRZ model (0.63) and sRPE model (0.62). In the case of TA$_{max}$ and the observed internal methods, a moderate association with SHRZ and sRPE (0.41) and a large with TRIMP$_B$ (0.54) were observed. A moderate or lesser correlation was

Table 1 Mean ± SD values of the different methods used in practice events.

	Mean	±SD
SHRZ	276,10	61,88
TRIMP$_B$	61,66	10,05
sRPE	765,32	174,87
TA	1766,96	386,47
TAMax	258,00	82,20
TA•min^{-1}	16,75	2,39
Acc•min^{-1}	8,38	1,24
Dec•min^{-1}	8,37	1,17

SHRZ Score = Edward's summated heart rate zones model; TRIMP = Banister's training impulse; sRPE = session-rating of perceived exertion; TA = total accelerations and decelerations during practice; TAMax = sum of all maximal accelerations and decelerations; TA·min^{-1} = total accelerations per minute; Acc·min^{-1} = accelerations per minute; Dec·min^{-1} = decelerations per minute.

Table 2 Correlations for external and internal workload variables. Pearson's correlation, variances, and significance.

External workload	Internal Workload	Lineal correlation (r)	R^2	*p*
TA	SHRZ	0.63**	0.40	<0,000
	sRPE	0.62**	0.39	<0,000
	$TRIMP_B$	0.78**	0.61	<0,000
TAMax	SHRZ	0.41**	0.64	<0,000
	sRPE	0.41**	0.64	<0,000
	$TRIMP_B$	0.54**	0.29	<0,000
$TA\bullet min^{-1}$	SHRZ	0.36**	0.60	<0,000
	sRPE	0.23**	0.05	<0,003
	$TRIMP_B$	0.26**	0.07	<0,000
$Acc\bullet min^{-1}$	SHRZ	0.38**	0.14	<0,000
	sRPE	0.24**	0.06	<0,002
	$TRIMP_B$	0.30**	0.09	<0,000
$Dec\bullet min^{-1}$	SHRZ	0.34**	0.12	<0,000
	sRPE	0.21**	0.04	<0,007
	$TRIMP_B$	0.24**	0.06	<0,002

SHRZ Score = Edward's summated heart rate zones model; TRIMP = Banister's training impulse; sRPE = session-rating of perceived exertion; TA = total accelerations and decelerations during practice; TAMax = sum of all maximal accelerations and decelerations; $TA{\cdot}min^{-1}$ = total accelerations per minute; $Acc{\cdot}min^{-1}$ = accelerations per minute; $Dec{\cdot}min^{-1}$ = decelerations per minute.

found between EL relative to time outcome and IL models. All relationships were statistically significant ($p \leq 0.01$).

Discussion

The main finding of this study is a low to a large correlation between models to monitor EL and IL in youth female basketball players, especially within IL models and TA. On the contrary, this research did not find significant correlations between the models related to the number of accelerations per unit of time and the IL.

This relationship, a priori, seems logical since a more significant physical demand requires the contribution of energy substrates and oxygen to the muscle tissue, increasing cardiac effort, and oxygen consumption. Despite this, there is a need to establish a proper relationship between physical demands and the physiological response of the athlete, in order to understand the dose-response relationship when training youth female basketball players.

Our findings observed a significant relationship among the studied models and various magnitudes of the relationship between external and internal load in female basketball ($r = 0.21$-0.78; $p \leq 0.01$). Our results also display a large correlation between TA and models using heart rate activity, $TRIMP_B$ (0.78) and SHRZ models (0.63), and a large correlation between TA and sRPE (0.62). This relationship has already been shown in basketball, emphasizing that external and internal loads are two separated constructs. It seems like this correlation between load variables was not sufficient, requiring a coefficient of determination higher than 50% ($r = 0.38$-0.61; $R^2 = 0.14-0.38$).[8] Compared to our results, we obtained larger correlation values, but also with lower R^2 values (0.045-0.613). Conversely, a meta-analysis including 13 studies on the relationship between physical demand and physiological responses in team sports, concluded showing consistent relationships between both constructs of load.[20]

To the authors' knowledge, no publications are showing a correlation between TA and internal load models. However, we have found within the literature related to Player Load (PL) models, a similar parameter based on the sum of accelerations, showing in different contributions a large and very large correlation with SHRZ models [0.61 (0.38-0.77); 0.80 (0.71-0.86)].[8] In the case of $TRIMP_B$, several reports have shown a "possibly large" correlation with PL values [0.54 (0.40-0.66)].[20] Regarding the perceptual model (sRPE) we observed a large correlation with TA (0.62). Considering the perceptual model (sRPE), we also observed a large correlation with the TA. In adult male basketball players, some authors have investigated this relationship between a perceptual model and PL™ (Player Load™) obtaining different results.[8,28] Svilar[28] showed a very large correlation (r=0.80; $p \leq 0.05$) while Scanlan has found a lower correlation (r=0.49; $p \leq 0.05$) between variables. Values showed by Svilar belong to Euroleague players gathered during the competitive period. We infer that these top-level players compete in most cases more than one game per week, exposing players to high-intensity competitive stress. So, it might be necessary to get a higher control of the training process, receiving smaller training doses, probably with less volume and more intensity, thus reporting greater values of external load and perceived effort, and finally obtaining higher values in correlation models. In contrast, Scanlan's study participants were semi-professional players with a lesser competitive load during weeks and maybe exposing players to different number and kind of tasks during practice, with variable volume and intensity. Despite using the same devices and gathering the same variables in both studies, the differences in correlation could be explained by the competitive level and, especially by the intensity and volume in the practices of the teams included in the sample. In the case of our results, the difference could also be explained by the sample characteristics, players with just one game per week, season period registered, type of training proposed, and the devices employed. These facts could be the reason why our results are more similar to those obtained in Scanlan's publication.

The correlations between models, previously described (EL: TA; IL: SHRZ, TRIMP, and sRPE), could be explained due to the time dependency of all the variables. Longer exposure time indicates a higher load value, with more accelerations or more heart activity that will be multiplied by time. Thus, we could suggest that all of these variables are quantifying the training or competition volume. It might be for this reason that our results are in agreement with some other authors' results, showing a large and very large correlation between internal and external load models in basketball and other sports.[8,20] On the contrary, we only found a large correlation between TAmax and $TRIMP_B$ (0.54), within internal models. This association could be explained by the fact that $TRIMP_B$ model considers the average and maximum heart rate value in every effort, so continuous and maximal accelerations could raise these parameters. The cardiovascular system works with a slight lag regarding the movements performed by the player, depending on the heart rate activity and the intensity of physical effort.[29] The same occurs between TAmax and sRPE (0.41), as the main factor that modifies the perception of the athlete is the intensity and duration of the physical efforts performed, more intensity higher fatigue perceived.[18]

On the contrary, our results seem to have a moderate relationship between $TRIMP_B$ and SHRZ models with $TA{\cdot}min^{-1}$, $Acc{\cdot}min^{-1}$, and $Dec{\cdot}min^{-1}$ and show a low correlation between sRPE and these external variables (Table 1). As we have mentioned previously, SHRZ, $TRIMP_B$, and sRPE models quantify load volume, and this might be the reason to explain the reduction of correlation value, with the results shown previously. In this case, external variables ($TA{\cdot}min^{-1}$, $Acc{\cdot}min^{-1}$, and $Dec{\cdot}min^{-1}$) are relative to time, and therefore, are more related to the density of load (units per minute).

The main limitation of the study is the amount of data collected. The initial data volume expected was higher, but several events were discarded during the process due to data signal inaccuracies. However, correlations were found in the study according to previous research, and new correlations and conclusions have been generated, providing these results interesting information to the scientific community and sports professionals. On the other hand, the use of heart rate and perceptual-based models could present some limitations described previously to determine team sports' physiological response.

In future investigations, it would be advisable 1) to use a bigger sample, allowing the use of other statistical tests such as R-Squared, aiming at obtaining higher predictive power between models; 2) combine other methods for the control of internal load that do not depend on heart rate or subjective methods; 3) establishing individual analyses could provide an understanding of the individual interactions within external and internal load values. Provided that the analyses are performed individually, we could find different conclusions since the physiological response to the same stimulus can differ significantly among players; 4) finally, it could be interesting to understand these relationships, specifically in competitive events.

Internal and external load models should be considered different constructs, and therefore, both must be quantified during the event (practice or competition) in youth female basketball. These results respond to the combination of many different factors within similar drills (space, number of players, number of opponents, or competition format) that contribute to determining the intensity in the context of intermittent team sports, especially in indoor team sports. For this reason, the relationship values found in the literature show significant differences.

Conclusion

To the best of our knowledge, this study is the first study aiming at establishing a relationship between external and internal loads in elite female youth basketball players. We can conclude that the assumption of strong relationships between external and internal loads in team sports can be misleading, as both models should be considered as different constructs. The findings of this study show a different level of correlation between external and internal load models, but current data highlights the importance of a continuous study of the complex relationship between physical demands and physiological responses in sports.

Conflict of interest

No potential conflict of interest was reported by the authors.

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Publicación IV

External load in semi-professional female basketball players during competition

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External load in semi-professional female basketball players during competition

Javier Espasa-Labrador[1,2]

Marta Carrasco-Marginet[1]

Azahara Fort-Vanmeerhaeghe[3,4]

[1]INEFC-Barcelona Research Group on Sport Sciences (GRCE), National Institute of Physical Education of Catalonia (INEFC), University of Barcelona, Barcelona (UB), Spain.

[2]Road to Performance Research, Coruña, Spain

[4]Ramon Llull University, FPCEE and FCS Blanquerna, SAFE research group, Barcelona, Spain.

[5]Segle XXI Female Basketball Team, Catalan Federation of Basketball, Esplugues de Llobregat, Spain.

Corresponding author

Azahara Fort-Vanmeerhaeghe
c/Císter, 34
08022 Barcelona
Spain
Phone: +34
E-mail: azaharafv@blanquerna.url.edu

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Introduction

Basketball, classified as a team sport within the category of invasion sports, is renowned for its high physical demands (Montgomery et al., 2010). It encompasses both aerobic and anaerobic elements, including frequent changes in direction, accelerations, decelerations, jumps, sprints, physical contact, and a requirement for complex technical and tactical skills (Schelling & Torres, 2016). These intricate skills demand high levels of coordination and significantly impact the game's physical prerequisites (Fox et al., 2017).

The examination and analysis of the physical load borne by players during official competition are critical to comprehend the sport's energy, kinematic, and technical demands. Understanding this load is paramount for designing training programs that optimize performance in competition and reduce the risk of injuries (Fox et al., 2018; Russell et al., 2021). One of the areas where this gender disparity is most pronounced is in the monitoring of physical load in women's basketball. There is limited evidence compared to men's basketball (Petway et al., 2020; Reina et al., 2017; Russell et al., 2021). A key reason for this is the lack of adequate economic resources, which has hindered women's basketball teams' access to advanced monitoring devices such as Electronic Portable Tracking Systems (EPTS) and the technical and human resources required for their implementation (Espasa-Labrador et al., 2023). The contrast in research between women's and men's basketball is particularly evident when it comes to describing the specific physical demands of competition. In many cases, studies with female players have focused on non-professional populations, such as young and amateur athletes. This is primarily due to the ease of access for researchers and the reluctance of high-level teams to share training data and physical characteristics (Espasa-Labrador et al., 2023, 2023). This lack of scientific evidence restricts the access of professional and semi-professional teams to specific information that would enable them to optimize training load management and establish a competitive reference framework.

Consequently, the imperative of external load monitoring has become inescapable for scrutinizing the correlation between the physical workload and performance metrics. These metrics encompass various facets like defensive rebounds, success in two- and three-point shots, accurate free throws, turnovers, assists, and fouls committed, as demonstrated by an extensive body of research on successful and unsuccessful basketball teams (Conte et al., 2018; García, Ibáñez, Gómez, & Sampaio, 2014; Gómez, Ibáñez, Parejo, & Furley, 2017). Additionally, a comprehensive investigation into situational variables is paramount since they profoundly influence athletic performance. These variables encompass shot precision contingent on players' roles, individual team attributes, and modifications in regulations (Ibáñez, García-Rubio, Gómez, & González-Espinosa, 2018).

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These external load variables have, at times, been studied by positions or quarters (García et al., 2020; Reina et al., 2020), and there have even been instances where physical demand data during competition has been correlated with in-game parameters(Gómez-Carmona et al., 2019), such as metrics collected in traditional or advanced basketball statistics. This could be a crucial point that contributes knowledge to sports environments with fewer resources, thus enabling access to information that can optimize the training process and reduce the likelihood of injuries.

This research project has two fundamental objectives: firstly, to quantify external load during competition in female basketball players within a semi-professional team; and secondly, to establish a correlation between the physical load experienced during competition and performance indicators that are characteristic of the game. External load values are different based on the position of the player, the time of the match, the competitive level of the opponent and fluctuations in the score. In addition, there is a relationship between load values and game performance indicators. The current study seeks to address this knowledge gap, providing critical insights to enhance the performance and well-being of female basketball players. It also aims to promote gender equity in sports science research.

Methods: design, participants, variables, and analysis

The study will be of an observational, descriptive, comparative, correlational, multivariate, retrospective, and cross-sectional design. This study will evaluate the load in matches played during the 2021/22 regular season of a semi-professional team competing in the Spanish second division. The sample, selected by convenience, will include a total of 12 players. None of the participants had any injuries at the time of the study. All games were monitored continuously using 12 EPTS (WIMU, Realtrack System® SL, Almeria, Spain) at a sampling frequency of 100Hz. The EPTS devices (81×45×15 mm, 70 g) were placed in the upper back using a custom-made adjustable top. Each player wore the same assigned device during five games to limit intersystem variability. The system-specific software, SPRO™ (version 987, RealTrack Systems® SL, Almería, Spain), was used to download and analyze data on physical demands.

Data from a total of five official game were collected via the inertial devices and stored immediately after each event on a university hard disk, together with the videos of those matches. As of the date of this record the data has not been accessed by any researcher. The selected sample was evaluated throughout the 2021/22 season (from March 2022 to May 2022).

In relation to external load, the following will be assessed: 1) the number and magnitude of accelerations; 2) the number of jumps and impacts; 3) the reported Player Load values. Conversely, the second category encompasses performance-related variables, including points scored, total shots attempted, total shots made, assists, rebounds, fouls committed, and fouls received. In addition, advanced basketball statistical indicators will be included, with a particular emphasis on factors such as game pace, offensive and defensive efficiency, true shooting percentage, turnovers and recoveries, and player participation.

For the variables described earlier, a descriptive statistics analysis will be conducted. The normality of data distribution will be assessed. Once normality is confirmed, the necessary statistical analysis tools will be used to achieve the previously described objectives, always considering the type of variables, data nature, and distribution. This analysis will be performed using the statistical software SPSS 22 (IBM Inc., New York, US).

Ethics and dissemination

The study was conducted in accordance with the ethical principles for biomedical research involving human subjects as established in the Declaration of Helsinki, revised in 2013 ("World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects," 2013), the recommendations of good clinical practices from the European Community (document 111/3976/88 of July 1990), and the Spanish legal regulations governing clinical research in humans (Royal Decree 561/1993 on clinical studies). Before the study commenced, each player was provided with information about the objectives and methods, as well as the potential benefits and risks. The study protocol was approved by the Ethics Committee for Clinical Research of the Sports Administration of Catalonia.

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CAPÍTULO 5

DISCUSIÓN

Esta tesis doctoral tuvo cuatro objetivos principales: 1) identificar y analizar los métodos, métricas y valores de referencia en la monitorización de la demanda física en el entrenamiento y la competición en el baloncesto femenino; 2) reconocer y describir los métodos, métricas y valores de referencia en la monitorización de la respuesta fisiológica en el entrenamiento y la competición en el baloncesto femenino; 3) describir los valores y la relación de la demanda física y la respuesta fisiológica en jugadoras jóvenes de baloncesto; y 4) monitorizar las demandas físicas de la competición y estudiar su relación con los parámetros de la estadística del baloncesto durante la temporada regular.

Para alcanzar el primero de estos objetivos se llevaron a cabo dos revisiones sistemáticas, las cuales representan, bajo el conocimiento del autor de esta tesis doctoral, el primer esfuerzo por sintetizar y analizar métodos y valores en esta población disponibles en la literatura científica, tanto en el estudio de la demanda física (Publicación I) como de la respuesta fisiológica a la carga (Publicación II) de la jugadora de baloncesto. Por otro lado, se describen valores de carga externa e interna, y la relación entre ambos constructos, a través de un estudio descriptivo y longitudinal llevado a cabo con jugadoras jóvenes de baloncesto (Publicación III). Por último, se presentó y evaluó positivamente un estudio descriptivo longitudinal que pretende monitorizar la competición en jugadoras adultas a lo largo de la temporada regular (Publicación IV).

¿Qué evidencia científica hay disponible en el estudio de la carga de entrenamiento y competición en el baloncesto femenino?

Las dos revisiones sistemáticas que forman parte de esta tesis doctoral (Publicación I y II) muestran como en el baloncesto femenino se han empleado diferentes métodos para la monitorización de la carga, tanto externa como interna (PS, análisis en vídeo, FC, IMU, etc.). Unos instrumentos de medida y métricas empleadas también en los jugadores masculinos (Petway et al., 2020; Russell et al., 2021), y destacándose un número similar de publicaciones incluidas, tanto en el estudio de la carga externa (n = 40) e interna (n = 44), aunque una parte de ellas estudiaron ambos constructos (n = 16). A pesar de esto, es importante resaltar que las publicaciones que estudiaron la carga, externa e/o interna en las jugadoras de baloncesto se concentran en la última década (en torno al 85% de los estudios). Una diferencia reseñable si se compara con los estudios en jugadores varones, en los que se observa un mayor volumen de publicaciones en el estudio de la demanda física, y además de forma escalonada en el tiempo, lo que podría indicar una adopción e implementación adelantada de nuevas herramientas de monitorización, en especial aquellas que usan tecnología (FC, IMU, etc.), respecto a las jugadoras. Este fenómeno, el de la incorporación tardía e infrarrepresentación, de la mujer como sujeto de estudio en las ciencias del deporte ha sido destacado en los últimos años (Costello et al., 2014;

Mujika & Taipale, 2019), y el cual se acentúa al segregar a las deportistas en diferentes niveles competitivos (Noordhof et al., 2022; Petway et al., 2020; Russell et al., 2021; Sandbakk et al., 2018), siendo las jugadoras jóvenes y de nivel amateur las que representan una mayoría entre los estudios publicados.

Además de identificar una gran heterogeneidad en los métodos empleados en la monitorización de la carga, también se observa una gran variedad al estudiar las métricas empleadas en cada uno de los métodos, ya sea en la descripción de la demanda física (distancia total *vs* distancia a alta velocidad, PL *vs* PL/min, etc.) como de la respuesta interna (RPE *vs* sRPE, SHRZ *vs* $TRIMP_B$, etc.). Asimismo, estas se han expresado de maneras diferentes, teniendo en cuenta la individualidad o el colectivo (promedio de la jugadora o promedio del equipo), el lapso de tiempo (cuartos en la competición, promedio diario o promedio semanal), el tipo de evento analizado (entrenamientos, competición o la combinación de ambos) o incluso las posiciones o la titularidad en la competición. Esta diversidad de métodos, métricas y cálculos empleados dificulta en exceso su aplicación en contextos de entrenamiento, ya sea en la generalización de valores de referencia con muestras similares, el uso de las tareas propuestas en las publicaciones en búsqueda de adaptaciones fisiológicas adecuadas, etc.

Por otro lado, del volumen de evidencia analizada (Publicación I y II) se debe destacar la calidad metodológica de los estudios. Si bien la mayoría de los estudios (> 65%) se identificaron como de una calidad metodológica buena al ser evaluados a través de la herramienta *Strengthening the Reporting of Observational Studies in Epidemiology* (Vandenbroucke et al., 2007), ninguna de estas publicaciones tuvo en cuenta las guías metodológicas propuestas en el estudio de la mujer deportista (de Jonge et al., 2019; Elliott-Sale et al., 2021). Un aspecto que limita la interpretación y generalización de los resultados en contextos aparentemente similares, ya que no se reportan datos muy relevantes en la caracterización de la muestra. Tal y como se ha señalado en la introducción de esta tesis doctoral, describir las características de muestra de forma adecuada es un elemento central en el estudio de la mujer deportista, y más importante aún al estudiar la respuesta fisiológica a la carga soportada por la jugadora. Más adelante se discutirá este aspecto de forma más detallada. Por último, en cuanto a los aspectos metodológicos, muchos de los estudios incluidos en ambas revisiones sistemáticas no proporcionaron información precisa sobre la dosis de entrenamiento o competición (el tiempo exacto del evento, el tipo y la duración de las tareas, el número de participantes, las posibles pérdidas de datos, etc.). Toda esta diversidad en el apartado metodológico podría explicarse por la propia naturaleza de los estudios, siendo probable que estos se hayan realizado con un carácter retrospectivo siempre en el marco de las dinámicas de entrenamiento y sin una metodología bien definida, en especial para abordar los diferentes inconvenientes del proceso de investigación.

Por todo lo anterior se sugiere establecer un consenso amplio y específico entre investigadores y entidades deportivas para la adecuada monitorización y uso de los valores de carga en el baloncesto femenino, prestando una atención especial a las características específicas de la mujer en la búsqueda de adaptaciones fisiológicas deseadas.

¿Cuáles son los métodos y métricas empleados mayoritariamente en el estudio de la carga en el baloncesto femenino?

En el estudio de la demanda física, los métodos de análisis en vídeo empleados inicialmente, tanto en el entrenamiento como en la competición, han ido siendo reemplazados por microsensores, como los GPS, LPS e IMU (Publicación I). Una implementación que aporta dos ventajas principales: 1) discriminar acciones de alta intensidad desarrolladas en lapsos de tiempo muy breves y con una precisión muy alta (suprimiendo además el sesgo del evaluador); y 2) aumentar la eficiencia del tiempo de recopilación y análisis de los datos de carga externa. Además, la sustitución de las herramientas de análisis también ha generado un cambio en las variables de estudio, reemplazando el análisis de la frecuencia de acciones (saltos, cambios de dirección, esprint, etc.) por otras métricas relacionadas con la intensidad, volumen y densidad que permiten evaluar la carga externa de la sesión o de una única tarea, de todo el equipo o de una sola jugadora. Ejemplos de estas métricas son el número y la magnitud de las aceleraciones y deceleraciones (Reina et al., 2022; Roell et al., 2020), la distancia total recorrida (Montgomery & Maloney, 2018; Portes et al., 2020), el PL o PL/min (Coyne et al., 2021; Ransdell et al., 2020), entre otras variables reportadas.

La evidencia científica disponible muestra que la variable más empleada en la monitorización de la carga durante el entrenamiento fue el PL, expresada en ocasiones como un valor absoluto, relativo al tiempo (Coyne et al., 2021; Reina Román et al., 2019), por tareas (Herrán et al., 2017) o calculando promedios semanales (Peterson & Quiggle, 2017). Diferentes maneras de expresar una métrica relacionada con el volumen y la densidad del entrenamiento, pero que, al ser una métrica acumulativa de aceleraciones en los diferentes planos, no permite identificar qué acciones específicas (y en qué plano de movimiento) contribuyen en mayor medida al aumento del sumatorio de carga de forma colectiva e individual. Una oportunidad, la de relacionar las acciones más intensas con el PL, de mejora futura que podría ayudar a individualizar los procesos de planificación de la carga. A pesar de esto, algunos autores han reportados valores de carga de referencia que permiten extraer dos ideas importantes. La primera es que aquellas tareas sin oposición parecen presentar una menor carga externa que las que cuentan con defensoras (Reina et al., 2019). La segunda es que el aumento de participantes desde el 3x3 hasta el 5x5 no se traduce en una mayor carga externa, sino lo contrario (Herrán et al., 2017; Reina et al., 2019). Por último, se han reportado otras métricas de interés como la cuantificación del número de aceleraciones (absolutas y relativas), encontrando que el número de aceleraciones descritas como máximas por minuto parecen ser similares en diferentes poblaciones y con diferentes dispositivos cuando se evalúa la sesión de entrenamiento completa (Arenas-Pareja et al., 2023; Reina et al., 2022) lo que podría hacernos pensar que en el baloncesto podrían existir un conjunto de variables (tiempo total de la sesión, orden y tipos de tareas, etc.) relacionadas con aspectos que podríamos denominar "culturales del entrenamiento" que condicionan la carga.

Por otra parte, en la competición, también se han empleado mayoritariamente los microsensores (Publicación I), pero a diferencia de los eventos de entrenamiento, en estos se han reportado también otras métricas de interés, como la distancia total recorrida (5x5: 2513 ± 1300 m; 3x3: 856,7 ± 220,8 m) a través de LPS (Montgomery & Maloney, 2018; Portes et al., 2020). Unos valores totales similares a la competición del baloncesto masculino que podrían ser explicados por las características comunes en el reglamento del tiempo y las dimensiones del campo, pero al comparar la distancia recorrida a alta velocidad, las jugadoras cubren una menor distancia a velocidades de entre 14-21 km/h (237 ± 170 vs 453 ± 263 m) (Petway et al., 2020; Portes et al., 2020). Y en relación a la métrica del PL la competición 5x5 muestra valores más bajos de carga que las tareas de 5x5 en el entrenamiento en jugadoras jóvenes (Portes et al., 2020), unos datos que alertan de que las demandas del entrenamiento exceden a las de la competición. Este fenómeno no debe ser considerado negativo per se, pero pone de relieve algunas reflexiones de interés. La primera es que los futuros artículos deberían incluir información sobre los objetivos condicionales de la sesión o de las tareas, lo que facilitaría la comprensión de los valores y las conclusiones obtenidas. Además, esta información debe aclarar qué métricas se utilizan para describir la intensidad, el volumen y la densidad, ya que, en esta tesis doctoral se ha observado que los valores de PL/min son mayores a medida que aumenta el nivel competitivo (Publicación I), lo que destaca una mayor densidad de acciones de alta intensidad. Y este hecho no se observa al evaluar las métricas relacionadas con la intensidad y el volumen. En segundo lugar, se podría comenzar a considerar que la competición en el baloncesto no es el evento más exigente de la semana para la jugadora. Y, por último, estos valores podrían indicar que el proceso de entrenamiento no cuenta con las características para optimizar o mejorar la condición física de las jugadoras.

En el caso de la carga interna, los métodos identificados en el estudio de la respuesta en el baloncesto femenino son mayoritariamente dos: el RPE (n = 28/44) y la monitorización de la FC (n = 27/44). Y, a diferencia de lo que ocurre en el estudio de la demanda física, se han empleado de forma constante a lo largo de las últimas, identificando publicaciones desde el año 2003 hasta la actualidad (Publicación II). Pero la mayor parte de los eventos que monitorizaron la FC son entrenamientos, ya que el equipamiento de sensores durante la competición no está permitido. Esta limitación del reglamento podría ser la razón principal por la cual se observe una mayor cantidad de publicaciones que utilizan métodos basados en la FC en competición de jugadoras jóvenes, ya que en categorías de formación no hay tanto control sobre estos aspectos, lo que hace más fácil el acceso a monitorizar estos eventos. Por otro lado, otros autores han evaluado parámetros fisiológicos como BLC (n = 5/44) o el VO_2 (n = 1/44), una presencia menor en la literatura científica, probablemente debido a los inconvenientes en su implementación regular en las dinámicas de entrenamiento y competición (métodos invasivos e incómodos). Aunque el uso de estos métodos en el baloncesto masculino cuenta con un mayor volumen de evidencia científica (J. L. Fox et al., 2017; Russell et al., 2021). Unos resultados que muestran que, de entre todos los métodos utilizados en los deportes de equipo para monitorizar la respuesta fisiológica, solo unos pocos métodos se han aplicado al baloncesto femenino, y no se ha encontrado evidencia sobre el análisis de niveles hormonales, en saliva o en plasma, parámetros en sudoración u orina, función muscular, etc., y su relación con la carga aguda y/o crónica.

El método más descrito en la literatura científica para la evaluación de la respuesta interna ha sido el RPE, probablemente esto se deba a sus dos ventajas principales: su ratio de coste-beneficio y ser un método no invasivo. Un fenómeno observado también en el baloncesto masculino (Russell et al., 2021). Aunque su facilidad de uso e implementación no debe hacer olvidar sus consideraciones metodológicas, como la identificación del constructo a medir, el rango temporal evaluado, las instrucciones precisas para atletas e investigadores, la elección de una escala adecuada, etc. (Halperin & Emanuel, 2020). Todas estas serán discutidas más adelante. Por último, en su aplicación al estudio de la respuesta interna, la mayoría de los autores emplearon el método de Foster (2001), multiplicando el valor reportado de RPE por el tiempo total del entrenamiento o competición. observándose un rango amplio de valores (253-942 UA). Un rango en el que también se encuentran los valores reportados en la Publicación III de esta tesis doctoral que estudió la PS de jugadoras jóvenes de alto nivel (765,3 ± 174,9 UA). Un hecho que podría explicarse en parte por la cultura del entrenamiento de baloncesto en el cual se utilizan sesiones en muchos casos con la misma duración.

En lo que respecta a la monitorización de la carga interna, los métodos más utilizados se basan en el registro de la FC. Algunas de las métricas empleadas incluyen la FC_{media} y la $FC_{máx}$, así como el cálculo de índices como el SHRZ y los $TRIMP_B$ o el tiempo que el corazón trabaja a determinados umbrales de intensidad (por ejemplo, más del 85% de la $FC_{máx}$). Estas métricas se han utilizado con el propósito de describir la intensidad, el volumen y la densidad de las sesiones de entrenamiento y las competiciones. Sin embargo, es fundamental destacar que, al igual que en otros deportes de equipo, el uso de métodos basados en la FC también presenta limitaciones

(Schneider et al., 2018). Entre estas limitaciones se incluye el retraso entre la actividad neuromuscular y la respuesta cardiovascular, así como la necesidad de una actividad prolongada para que se produzca una actividad cardiovascular significativa. Un fenómeno que se ha observado en esta tesis doctoral al relacionar la carga externa e interna (Publicación III). Además de esto, la respuesta cardiovascular a cualquier estrés es altamente variable e individual y depende en gran medida del estado del sistema nervioso autónomo y los niveles hormonales individuales (Achten & Jeukendrup, 2003; Buchheit, 2014), por lo que llevar a cabo análisis promedios o comparaciones entre jugadoras podría llevar a los evaluadores a interpretaciones erróneas. Para evitar este error, se sugiere un enfoque más individualizado que considere el total de trabajo cardíaco desempeñado en los momentos más intensos y densos del entrenamiento y la competición, en lugar de llevar a cabo un análisis global de la sesión o a través de promedios del equipo.

En el uso de métodos subjetivos se han identificado algunas limitaciones ¿cómo podemos disminuir su impacto en el proceso de monitorización de la carga?

Se ha resaltado anteriormente que entre los resultados de esta tesis doctoral se resalta un uso amplio de métodos subjetivos (Publicación II). Y aunque en la implementación de cualquier sistema de monitorización se deben estudiar todos los aspectos metodológicos y limitaciones en cada uno de los métodos empleados, aquellos de naturaleza subjetiva son más sensibles a estos problemas, pudiendo incluso llegar a hacer utilizados en favor de determinados intereses o sesgando la interpretación de los resultados si no se utilizan procedimientos claros y consistentes (Halperin & Emanuel, 2020). Por estos motivos aquellos autores que han propuesto dichos métodos han resaltado la necesidad de implementar medidas que limiten estas problemáticas (sesgos, interferencias en la respuesta, etc.), enfatizando principalmente en la adecuada instrucción de las deportistas (Foster, Florhaug, et al., 2001), así como velar por la adecuada sistematización de elementos extrínsecos e intrínsecos de la jugadora.

En relación al primer punto, establecer un período de familiarización es una práctica habitual en la literatura científica (Batalla-Gavalda et al., 2022; Brini et al., 2021). Ahora bien, se debe resaltar que la mera exposición podría no ser suficiente, y que se requiere de un acompañamiento pedagógico de la jugadora. Esto implica que investigadores y/o entrenadores deben ser una guía constante y continua, siendo capaces de explicar de forma clara y precisa qué significa cada punto de la escala empleada y resolver todas las dudas que puedan surgir, incluso aportando ejemplos y comparaciones que permitan concretar el valor en la escala utilizada, un punto especialmente relevante en jugadoras jóvenes. Por otro lado, a lo largo de los años se han añadido algunas claves metodológicas a través de las cuales disminuir los sesgos y la influencia del grupo, asegurando una mayor validez y precisión del dato. Entre estas se resaltan la importancia que la respuesta sea recogida de forma individual, sin la influencia del grupo u otras compañeras o más miembros del cuerpo técnico (Willberg et al., 2023). También el uso de herramientas de recopilación que permitan la autonomía en la respuesta, como el uso de cuestionarios a través de herramientas digitales como aplicaciones móviles (Paulauskas et al., 2019).

Aun así, establecer estos mecanismos no asegura que la jugadora reporte datos fiables, llegando incluso a emplear el método a su favor. Por este motivo se hace imprescindible el estudio de los datos de forma diaria (Haddad et al., 2017), comparando estos con otros métodos e incluso con las propias percepciones del evaluador (Foster, Heimann, et al., 2001). La actuación en base a estos datos debe realizarse con cautela, ya que es probable que si la jugadora percibe que la toma de decisiones, en especial si estas se alinean en contra de sus intereses, es una consecuencia directa de las respuestas reportadas podría modificar cada vez sus respuestas, ocultando percibir una carga muy baja o muy alta, malestar o incluso molestias que derivan en lesiones.

¿La evidencia científica disponible tiene en cuenta las características hormonales de la jugadora de baloncesto al monitorizar y evaluar la carga?

En la introducción y resultados (Publicación I y II) de esta tesis doctoral se ha puesto de manifiesto que la mayoría de los métodos empleados en la monitorización de la carga en el baloncesto femenino ya han sido empleados en el baloncesto masculino y otros deportes de equipo, lo que debe ser considerado como un aspecto positivo, ya que se han mostrado como válidos, precisos y específicos. A pesar de esto, entre las publicaciones que estudiaron la carga externa (Publicación I) y la carga interna (Publicación II) no se tuvieron en cuenta las características fisiológicas de la mujer, en especial el impacto del ciclo menstrual en los valores de carga. Un aspecto importante al encontrar investigaciones previas que han relacionado el ciclo menstrual con síntomas físicos y psicológicos que pueden afectar de forma negativa a las actividades de la vida cotidiana (Kissow et al., 2022). Un fenómeno que también se observa en el contexto deportivo, donde se ha destacado que la mayoría de las deportistas (que no utilizan anticonceptivos hormonales) sufren síntomas negativos que afectan a su rendimiento, como dolor abdominal y de espalda, dolor de cabeza o migraña, etc. (Bruinvels et al., 2022; Martin et al., 2018). Una circunstancia que sitúa a estas jugadoras en desventaja frente a compañeras y rivales y que en la monitorización de la carga podría tener un impacto significativo (alteración en la percepción de la carga, cambio en la respuesta cardiovascular frente a estímulos cotidianos, etc.). Este es uno de los motivos principales por los que en los últimos años se han desarrollado guías para la realización de investigación con participantes femeninas en el ámbito del deporte, en las que se destaca el estudio de los niveles hormonales y sus efectos en la caracterización de la muestra, facilitando un análisis e interpretación de los resultados individual (Elliott-Sale et al., 2021).

Si bien el estudio del perfil hormonal y sus cinéticas es altamente complejo, en especial por la necesidad de establecer en qué momento del ciclo menstrual se encuentra la deportista, esto es un punto fundamental, ya que podría alterar los procesos fisiológicos que se registran a través de los métodos descritos anteriormente. En una revisión sistemática reciente, De Jonge y colaboradores (2019) enumeran los diferentes métodos empleados para ello: 1) exploración folicular en serie mediante ultrasonografía transvaginal; 2) conteo de los días en el calendario; 3) medición de la temperatura corporal basal; 4) análisis de la cristalización salival; 5) monitorización de la hormona luteinizante en orina; 6) análisis de hormonas en saliva; 7) análisis de las hormonas en suero sanguíneo (de Jonge et al., 2019). Y de entre estos, el análisis hormonal a través de análisis serológico se destaca como el estándar de mayor calidad para establecer el momento del ciclo menstrual, pero su uso requiere de un instrumental y conocimiento específico y una dotación presupuestaria mayor que en el caso de la investigación en hombres (Elliott-Sale et al., 2021). Y quizás estos son algunos de los motivos por los que en esta tesis doctoral solo se incluyó una publicación que tuvo en cuenta este aspecto en la caracterización de las jugadoras, pero en la cual los autores emplearon cuestionarios autorreportados (fase del ciclo menstrual, duración del último ciclo, uso de anticonceptivos, etc.) (Arenas-Pareja et al., 2023). Un resultado que nos debe hacer reflexionar sobre cómo se ha llevado a cabo la investigación de la jugadora de baloncesto hasta la fecha en relación a la monitorización de la carga y el uso de los datos que de estos se obtienen.

Si bien se ha destacado que hasta la fecha no se dispone de evidencia científica suficiente para adaptar el entrenamiento a las fases del ciclo menstrual (McNulty et al., 2020), llevar a cabo un registro del ciclo menstrual se destaca como un instrumento de gran ayuda en la comprensión de las variaciones en la respuesta de otros sistemas y en el rendimiento (de Jonge et al., 2019). Para ello se han sugerido recientemente la implementación de aplicaciones móviles específicas para el seguimiento de las fases del ciclo menstrual y sus síntomas (en especial si existen sospechas de irregularidades o disfunciones), acompañando su uso de procesos pedagógicos que incluyan estrategias proactivas en el manejo del ciclo menstrual (Bruinvels et al., 2022; Okholm Kryger et al., 2022).

¿Puede el estudio de la relación entre la demanda física y la respuesta fisiológica ayudar a mejorar los procesos de monitorización de la carga y tomar mejores decisiones?

En la introducción de esta tesis doctoral se ha expuesto, al abordar la relación entre la carga externa e interna, cuatro posibles escenarios (Figura 8), resaltando además que esta es una relación contextual, dinámica e individual. El estudio de esta relación había sido descrito en la literatura como fundamental para mejorar los procesos de monitorización de la carga en deportes de equipo y, por lo tanto, para tomar decisiones más informadas e individuales a lo largo del proceso de entrenamiento (Burgess, 2017; McLaren et al., 2018). Estos hallazgos se han replicado de forma similar en esta tesis doctoral al estudiar la relación de la carga externa e interna en jugadoras jóvenes durante el entrenamiento (Publicación III). A pesar de esto, es necesario esclarecer algunos puntos para poder llegar a cumplir estos objetivos.

El primero de estos es la necesidad de tener en cuenta las limitaciones propias de los métodos de monitorización utilizados al estudiar esta relación, un aspecto que se ha discutido con anterioridad. En segundo lugar, es necesario relacionar de forma adecuada las métricas de cada constructo, emparejando aquellas que evalúan la intensidad, el volumen o la densidad. De entre estos la intensidad es el que presenta las mayores dificultades y donde se observan correlaciones de menor nivel (Publicación III). El motivo principal es que estas acciones son producidas a través de procesos glucolíticos, y si no se mantienen en el tiempo no se ven reflejadas en el sistema cardiovascular (López Chicharro & Fernández Vaquero, 2008; Scanlan et al., 2014), que es el sistema del organismo más monitorizado en el baloncesto femenino (Publicación II). Por lo que, si no se implementan otros métodos, se recomienda estudiar la relación entre la demanda y la respuesta a través del volumen o de densidad, como por ejemplo podría ser la relación entre la distancia total recorrida, el PL o la suma total de aceleraciones con métricas como el SHRZ o el sRPE, donde la evaluación de la carga interna contempla el tiempo total de la sesión. Para mejorar la comprensión del impacto de las acciones de alta intensidad podrían incorporarse otros métodos que ya han sido descritos en la literatura, como la evaluación del daño muscular a través de análisis de fluidos corporales, como saliva o plasma (Ascensão et al., 2008; Kamarauskas & Conte, 2022; Young et al., 2012).

A pesar de esto, la evidencia de la que se dispone actualmente podría ser un buen punto de partida si se tienen en cuenta todos los factores descritos en la introducción de esta tesis y los resultados de la Publicación III. Además, incluir un análisis de la carga aguda y crónica como proponen Bourdon y colaboradores (2017) podría ser un gran complemento en la comprensión de cómo el organismo responde a las cargas de trabajo.

¿Cuáles son los elementos principales que modifican la demanda física de la jugadora y qué relación tiene con el éxito durante el juego?

Al estudiar la evidencia científica disponible sobre la monitorización de la carga durante la competición en el baloncesto femenino (Publicación I y II) se observa que existe una menor cantidad de publicaciones en comparación con el baloncesto masculino (Petway et al., 2020; Russell et al., 2021). Además, se destaca una gran diversidad de formas de presentar los valores de carga, lo que dificulta la comparación entre ellos y, lo que es más importante, la identificación de los factores determinantes que más influyen en dichos valores.

Esta problemática ha preocupado a investigadores con anterioridad, lo que ha promovido analizar la carga por posiciones o cuartos, tanto en el baloncesto femenino como en el masculino (García et al., 2020; Reina et al., 2020). No obstante, y aunque sin duda estos estudios aportan claridad sobre las demandas físicas, se debe resaltar que son una instantánea final sobre un suceso pasado, sin profundizar en la complejidad de los elementos, y sus relaciones, que modulan la carga durante el propio evento. Incorporar a investigaciones futuras propuestas relacionales entre la carga y los parámetros propios del juego, como por ejemplo las fluctuaciones en el marcador (Gómez-Carmona et al., 2019) podría ser muy valioso, disponiendo así de información en tiempo real. Un punto que podría ser interesante especialmente para equipos y clubes que no disponen del acceso a tecnología (IMU, LPS, etc.).

Además de considerar la relación entre el marcador y la carga, podría ser pertinente incluir otros factores inherentes al juego, ya que ninguna de las publicaciones analizadas en esta tesis se ha ocupado de estos aspectos. Entre las posibles variables a incluir se propone evaluar la densidad de trabajo (número de interrupciones del juego y la duración de la mismas), la participación en el juego de la jugadora (el número de acciones de éxito o la aportación de puntos al marcador), el ritmo de juego (número de posesiones jugadas o eficacia en las acciones), las características del rival (el nivel competitivo o el estilo de juego), las características individuales de las jugadoras rivales (antropométricas o de eficacia en las acciones técnico-tácticas), la relevancia del partido (rival histórico o la disputa en la clasificación), etc. Comprender estos factores podría ser de gran utilidad para anticipar las demandas del próximo evento, optimizar la planificación del entrenamiento e incluso adoptar decisiones en tiempo real. La investigación y descripción del impacto de estos factores en la carga constituye el objetivo de la cuarta publicación de esta tesis doctoral (Publicación IV).

Conclusiones

Esta tesis doctoral ofrece un marco de referencia valioso que describe y analiza la evidencia científica actual en relación a las demandas físicas y las respuestas fisiológicas del baloncesto femenino y la relación entre ambos constructos de la carga.

A continuación, se presentan las principales conclusiones:

- En el baloncesto femenino se han empleado pocos de los métodos y métricas descritos en los deportes de equipo para la monitorización de la carga externa e interna, destacándose principalmente el análisis en vídeo, el uso de sistemas de posicionamiento y sensores inerciales en el primer caso, y la RPE y la FC en el segundo. Además, se observó un menor número de publicaciones en comparación con el baloncesto masculino.

- Entre los estudios científicos disponibles se identificó una gran heterogeneidad en el uso de métodos y métricas para la monitorización, utilizando diferentes métricas para describir la intensidad, el volumen o la densidad. Independientemente del nivel competitivo, las métricas más utilizadas en el estudio de la demanda física son el PL y el PL/min, mientras que la sRPE y las diferentes métricas de FC suponen casi la totalidad de la evidencia científica cuando se estudia la respuesta interna de la jugadora.

- En el estudio del entrenamiento se ha observado que aquellas taras sin oposición suponen menores niveles de carga externa, y se identificaron las tareas de 3x3 como las más exigentes, incluso por encima de aquellas que pretendían simular la competición. Por otro lado, al evaluar la respuesta interna se observó que esta depende de muchos factores, siendo la variable de densidad un punto clave para comprender la respuesta cardíaca y la percepción subjetiva.

- El análisis en vídeo de la competición del baloncesto femenino mostró que a mayor nivel competitivo las jugadoras pasan más tiempo de pie o caminando, además de disminuir la frecuencia de acciones de salto. A pesar de esto, la competición oficial se identificó como el escenario en el que la jugadora desarrolla los niveles más altos de PL/min, un fenómeno que se acentúa en las jugadoras de mayor nivel. Por otro lado, las jugadoras muestran valores similares de distancia total recorrida a los que se observa en el baloncesto masculino, mientras que la distancia a alta velocidad es menor.

- En la aplicación de los métodos de monitorización de la carga se observaron diferencias metodológicas. En ocasiones se incluyeron los tiempos de descanso en el análisis de la demanda física mientras que otros no. Además, se encuentran algunas inconsistencias metodológicas al emplear la monitorización de la FC, como la falta de información de cómo se establece la $FC_{máx}$ de cada jugadora. Por último, solo una publicación tuvo en cuenta las características hormonales de la mujer deportista en el estudio de la carga. En el futuro todos estos aspectos deberán ser resueltos para así comprender mejor las demandas del baloncesto y la respuesta de la jugadora.

- Los resultados de esta tesis doctoral (Publicación III) indican que asumir relaciones sólidas entre la dosis y la respuesta podría ser erróneo debido al funcionamiento complejo de los sistemas corporales. Además, estas relaciones varían constantemente por la interacción de un gran número de factores, lo que hace necesario estudiar cada evento y jugadora de forma independiente para así evaluar y planificar el proceso de entrenamiento a lo largo de la temporada.

Limitaciones y líneas de investigación futuras

Esta tesis doctoral presenta algunas limitaciones que es necesario destacar. En la Publicación I y II no fue posible llevar a cabo un meta-análisis debido al alto nivel de heterogeneidad en los métodos y métricas empleados en las publicaciones incluidas. En primer lugar, los estudios que evaluaron la carga externa presentan algunos déficits de información que no permiten comparar de forma precisa las demandas físicas de las tareas de entrenamiento o de la competición en las diferentes poblaciones estudiadas (Publicación I). Por otro lado, al estudiar la respuesta interna de la jugadora de baloncesto pocas publicaciones aportaron información sobre las características fisiológicas de las deportistas, un hecho que limita la comprensión de la carga interna por la falta de un contexto individual (Publicación II). En el caso de la tercera publicación la limitación principal fue la cantidad de datos recopilados al perder muchos registros por fallos de la tecnología empleada. Además, y tal como se ha resaltado en esta tesis doctoral, el uso de modelos basados en la frecuencia cardíaca y la percepción puede presentar algunas limitaciones en el estudio de la respuesta fisiológica en estas poblaciones.

Por último, esta tesis doctoral no cuenta en el momento de su depósito con los resultados del último estudio publicados en una revista de impacto como el resto de los trabajos (Publicación IV). Con estos datos, que estudian las demandas físicas en la competición oficial del baloncesto femenino se pretende aportar algunas respuestas a los interrogantes sin responder, como es conocer la relación entre la carga y las variables del tiempo (útil, total, etc.) y con variables de rendimiento propias del juego (eficiencia y eficacia, ritmo de juego, número de acciones técnico-tácticas realizadas, etc.).

Entre las líneas de investigación futura que se proponen en esta tesis doctoral cabe destacar la necesidad de un consenso entre investigadores y cuerpos en los procesos de monitorización de la carga, prestando una atención especial a las características individuales de la jugadora en el momento de monitorizar ambos constructos de la carga, pero en especial la respuesta fisiológica. Además, sería de gran ayuda emplear otros métodos en la monitorización de la carga interna ya utilizados en otros deportes de equipo con el objetivo de comprender de forma más precisa y detallada el comportamiento de los diferentes sistemas del organismo y relacionar estos con la demanda física del entrenamiento y la competición. Asimismo, el estudio de la carga externa analizando los elementos primarios que configuran las tareas (número de participantes, espacio utilizado, densidad de trabajo, nivel del rival, interacciones entre jugadores, fluctuaciones en el marcador, etc.) podría aportar una visión enriquecida de las demandas del entrenamiento que permitan optimizar el proceso de entrenamiento.

En la generación y divulgación de nuevo conocimiento científico, publicaciones futuras deberán incorporar las consideraciones metodológicas propuestas en la literatura y discutidas en esta tesis doctoral al estudiar a la jugadora de baloncesto. Entre las que se resalta la necesidad de detallar las características individuales de la muestra (el momento del ciclo menstrual, el uso de anticonceptivos, etc.). Esto permitirá una mejor contextualización de los valores de carga reportados, independientemente del método empleado, a lo largo de las fluctuaciones hormonales durante el ciclo menstrual. Pudiendo facilitar la identificación de fluctuaciones en parámetros de intensidad (aceleraciones y deceleraciones máximas) y volumen (metros recorridos), de respuesta fisiológica (FC y/o VO_2), y en la relación entre la dosis y la respuesta a lo largo del proceso de entrenamiento y la competición.

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ANEXOS

Anexo I

Internal and external training loads by position during basketball training in elite female young basketball players.

Comunicación póster en Congreso Internacional "Congress in Interdisciplinary Physical Prevention and Rehabilitation", Granada 2017

INTERNAL AND EXTERNAL TRAINING LOADS BY POSITIONS DURING BASKETBALL TRAINING IN ELITE FEMALE YOUNG BASKETBALL PLAYERS

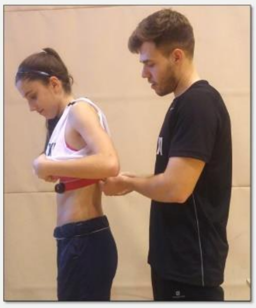
Javier Espasa Labrador[1]*, Toni Caparros Pons[1,2] y Azahara Fort Vanmeerhaeghe[3,4]

[1]National Institute of Physical Education of Catalonia (INEFC), University of Barcelona, Barcelona, Spain; [2]SPARG Research Group, University of Vic, Vic, Spain; [3]Blanquerna Faculty of Psychology, Education Sciences and Sport (FPCEE), Universitat Ramon Llull, Barcelona, Spain; [4]Segle XXI Female Basketball Team, Catalan Federation of Basketball, Esplugues de Llobregat, Spain.

Introduction

The controlling and monitoring of training load in team sports have acquired a big importance in the modern competition where sports staff use all of data to improve performance periodizing the training process and reducing injuries and overtraining[1].

The aim of this prospective and longitudinal study was to describe internal and external training load during a competitive period in eleven elite female young basketball players (age 16.3±1.04 years, height 181.65±5.79 cm and body mass 71.17±9.56 kg.).



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Materials and methods

Training load data were collected over 7 weeks across 35 sessions, adding a total of 164 registered events, each player contributed with 13.67±5.96 sessions. Players were categorized based on three different playing positions (guards, forwards and centers). Internal training load was estimated using session ratings of perceived exertion[2] (sRPE) and summated heart rate zones[3] (SHRZ) models. External training load was determined through accelerometry outputs (Polar Team Pro, Polar Electro Oy, Finland): 1) sum of total accelerations and decelerations (TA); 2) sum of total accelerations and decelerations per minute (TA/min); 3) total external training load as summated accelerations zones (SAZ). ANOVA analysis was performed to determine if there were significant differences between groups. Subsequently, a post-hoc analysis was performed with the Bonferroni test to establish between which groups there were differences.

Results

Results showed significant differences between guards and forwards for TA/min (.003) and forwards and centers for SHRZ (.037), TA/min (.010) and SAZ (.014) variables ($p \leq .05$). Guards presents higher values than forwards of TA/min (G: .029; F: .27) and centers perform a higher number of SHRZ, TA/min and lower of SAZ than forwards (C: 292.44, .29 and 270.04 respectively; F: 264.11, .27 and 322.89 respectively). However, there aren't significant differences between any group to sRPE and TA. Neither significant differences between guards and centers to any variable.

Descriptives

Dependent Variable	Position	N	Mean (AU)	Std. Deviation
SHRZ	Guards	44	274,05	67,04
	Forwards	66	264,11	60,57
	Centers	54	292,44	56,35
sRPE	Guards	44	760,27	194,44
	Forwards	66	763,87	165,012
	Centers	54	771,20	172,99
TA	Guards	44	1852,93	425,28
	Forwards	66	1694,71	378,66
	Centers	52	1789,02	358,11
TAmin	Guards	44	,29	,042
	Forwards	66	,27	,040
	Centers	52	,29	,032
SAZ	Guards	44	306,25	92,048
	Forwards	66	322,90	117,35
	Centers	54	270,04	82,01

Multiple Comparisons

Bonferroni

Dependent Variable	(I) Position	(J) Position	Sig.
SHRZ	Guards	Forwards	1,000
		Centers	,420
	Forwards	Guards	1,000
		Centers	,037*
	Centers	Guards	,420
		Forwards	,037*
sRPE	Guards	Forwards	1,000
		Centers	1,000
	Forwards	Guards	1,000
		Centers	1,000
	Centers	Guards	1,000
		Forwards	1,000
TA	Guards	Forwards	,110
		Centers	1,000
	Forwards	Guards	,110
		Centers	,567
	Centers	Guards	1,000
		Forwards	,567
TAmin	Guards	Forwards	,003*
		Centers	1,000
	Forwards	Guards	,003*
		Centers	,010*
	Centers	Guards	1,000
		Forwards	,010*
SAZ	Guards	Forwards	1,000
		Centers	,231
	Forwards	Guards	1,000
		Centers	,014*
	Centers	Guards	,231
		Forwards	,014*

*. The mean difference is significant at the 0.05 level.

Conclusions

In conclusion, different positions present differences regarding to physical and physiological demands during elite female young basketball players training in competitive period. Therefore, staff should adjust the training process to each player's position, personalizing the adaptations with the objective of raising performance in competition.

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javierespasa12@gmail.com

@JaviEspasa

INEFC Generalitat de Catalunya UNIVERSITAT DE BARCELONA SEGLE XXI

Anexo II

Comparison between training load and preseason load in young elite female basketball players.

Comunicación póster en Congreso Internacional "Complex Systems in Sport", Barcelona 2017

COMPARISON BETWEEN TRAINING LOAD AND PRESEASON COMPETITION LOAD IN YOUNG ELITE FEMALE BASKETBALL PLAYERS

Javier Espasa Labrador[1]*, Toni Caparros Pons[1,2] y Azahara Fort Vanmeerhaeghe[3,4]

[1]National Institute of Physical Education of Catalonia (INEFC), University of Barcelona, Barcelona, Spain; [2]SPARG Research Group, University of Vic, Vic, Spain; [3]Blanquerna Faculty of Psychology, Education Sciences and Sport (FPCEE), Universitat Ramon Llull, Barcelona, Spain; [4]Segle XXI Female Basketball Team, Catalan Federation of Basketball, Esplugues de Llobregat, Spain.

Introduction

This small study in the form of poster is a part of the development of a doctoral thesis called **monitorization and optimization of training loads in basketball**. Despite the advances in the sports sciences for the improvement and development of efficient training programs, competition data is not available yet and, therefore, training processes can not be optimized for the improvement of sport performance and prevention and prediction of injuries.

Objective

The aim of this study was **to compare the physical and physiological demands of an official preseason competition and 5 to 5 (5c5) training sessions in young elite basketball players.** There were a total of 4 registered events (2 official matches and 2 training sessions) used for this research. The participants were 7 young elite basketball players with an average age of 16.3±1.04 years, a height of 181.65±5.79 cm and a body mass of 71.17±9.56 kg.

Materials and methods

The device used was the Polar Team Pro (Polar Electro Pro, Polar Electro Oy, Finland) which incorporates a heart rate (HR) sensor and an accelerometer. **For the analysis of the physiological demands (internal load)** (Gabbett, 2017) the data collected was: 1) the minimum, average and maximum HR during the event; 2) the time in each heart rate zone (zone 1 = 50-60% HRmax, zone 2 = 60-70% HRmax, zone 3 = 70-80% HRmax, zone 4 = 80-90% HRmax, and zone 5 = 90-100% HRmax); 3), and the sum of the heart rate score (SHRZ Score) was calculated (Edwards, 1993). **The accelerometry (external load)** (Montgomery, Pyne, & Minahan, 2010) variables observed were: 1) the number of accelerations and decelerations in each zone (Accelzone1: -50.0 to -4.0m/s2; Accelzone2: -3.9 to -3.0m/s2; Accelzone3: -2.9 to -2.0 m/s2; Acceleration4: -1.9 to 0.5m/s2; Accelzone5: 0.5 to 1.99m/s2; Accelzone6: 2.0 to 2.99m/s2; Accelzone7: 2.9 to 3.99.0m/s2; Accelzone 8: 4.0 to 50.0m / S2); 2) the total amount of accelerations (TA); 3) the accelerations per minute rate (TA/min). All statistical analyses were performed using IBM SPSS Statistics (SPSS, version 21 for MacOS, SPSS Inc, Chicago, IL). **The statistical significance accepted was $p \leq 0.05$.**

Results

The results obtained show that there are statistically significant differences between training and competition. For the physical demands we observed that there are statistically significant differences for the variables of: 1) TA (.000); 2) TA/min (.000); 3) Accelzone2 (.000); 4) Accelzone3 (.000); 5) Accelzone4 (.015); 6) Accelzone5 (.002); 7) and Accelzone6 (.006). On the other hand, analyzing the physiological responses of events we found that there are differences as well: 1) HRavg (.009); 2) HRmax (.000); 3) HRzone2 (.022); 4) HRzone3 (.000); 5) HRzone4 (.046); 6) HRzone5 (.000).

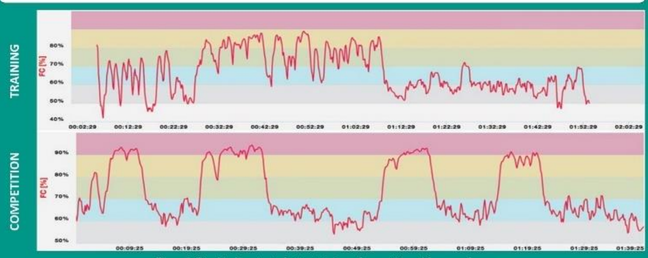

Figure 1: Graphical heart rate during training and competition of the same player.

Table 1: Results of mean and standars deviations of variables between events.

Group Statistics

Variable	Event	N	Mean	Std. Deviation
HRmin	Match	14	81,29	17,77
	Training	14	73,36	13,43
HRavg	Match	14	140,29	10,48
	Training	14	129,50	9,80
HRmax	Match	14	196,50	6,99
	Training	14	178,93	13,74
HRZone1	Match	14	0:25:54	0:12:07
	Training	14	0:24:50	0:10:52
HRZone2	Match	14	0:16:36	0:10:57
	Training	14	0:25:20	0:07:39
HRZone3	Match	14	0:09:11	0:07:24
	Training	14	0:26:04	0:05:56
HRZone4	Match	14	0:17:27	0:06:30
	Training	14	0:11:27	0:08:31
HRzone5	Match	14	0:14:49	0:09:38
	Training	14	0:00:08	0:00:31
Accelzone1	Match	14	11,36	5,97
	Training	14	12,29	7,05
Accelzone2	Match	14	75,64	22,91
	Training	14	154,00	66,45
Accelzone3	Match	14	255,50	50,88
	Training	14	388,43	85,04
Accelzone4	Match	14	202,71	39,79
	Training	14	257,21	66,93
Accelzone5	Match	14	188,14	37,21
	Training	14	252,07	58,15
Accelzone6	Match	14	286,50	70,19
	Training	14	476,21	140,97
Accelzone7	Match	14	57,14	23,65
	Training	14	74,29	25,73
Accelzone8	Match	14	13,14	8,84
	Training	14	18,43	9,35
SHRZ Score	Match	14	230,65	56,14
	Training	14	200,26	48,27
TA	Match	14	902,00	192,36
	Training	14	1380,86	359,49
TA/min	Match	14	,162	,034
	Training	14	,215	,032

HRmin: minimum heart rate; HRavg: average heart rate; HRmax: maximum heart rate; HRzone 1 = 50-60% HRmax; HRzone 2 = 60-70% HRmax; HRzone 3 = 70-80% HRmax, HRzone 4 = 80-90% HRmax; HRzone 5 = 90-100% HRmax; SHRZ Score: sum of the heart rate score; TotalAccel: sum of total accelerations and decelerations; Accelzone 1: -50.0 to -4.0m/s2; Accelzone 2: -3.9 to -3.0m/s2; Accelzone 3: -2.9 to -2.0 m/s2; Accelzone 4: -1.9 to 0.5m/s2; Accelzone 5: 0.5 to 1.99m/s2; Accelzone 6: 2.0 to 2.99m/s2; Accelzone 7: 2.9 to 3.99 m/s2; Accelzone 8: 4.0 to 50.0m/s2); Accel/min: the accelerations per minute rate.

Discussion

Once analysed means and standards deviations (SD) obtained (Table 1) in each of the variables related to training and competition loads with statistically significant differences, we observed that HRavg and HRmax are greater during the competition. **This data leads us to think that the intensity during the competition is higher.** The player spends more time in HRzone2 and HRZone3 (specially) during training than in competition. This is because the efforts during the training sessions are longer, although they consist of less demanding tasks, while in competition, this zone seems to be a transition band, either towards lower beating rates (rest on the bench) or towards maximum beating rates (time in court). **See Figure 1.**

The values of HRzone4 and HRZone5 are higher in a match. **We think this might be because the player always works at maximum heart beats during the competition** and the one who spends the most of the time in HRzone4 might be due to either the times of breaks that occur while they are on the court or a not well configured maximum heart rate value into the software. Despite this, **the SHRZ Score average tells us that the total load is larger in training sessions.** This is probably due to the longer duration of the session and more sustained efforts over the time, but less intense. This idea is reinforced by analyzing the mean in the HRZone3. In addition, the players work for less minutes for the duration of the match itself.

After analyzing the variables of accelerometry we can observe that the magnitudes of the accelerations in the training are greater for Accelzone2, Accelzone3, Accelzone4, Accelzone5 and Accelzone6, also that zones Accelzone3 and 6 are specially lower in competitions. **We believe these areas are where this population develops their majority of accelerations and decelerations submaximals and maximals (-2.99 to -2.0m/s2 & 2.0 to 2.99m/s2).**

Previously we mentioned that SHRZ Score was statistically different between events. **Perhaps this is because there is a greater amount of acceleration during the training session (TotalAccel).** And internal load is the consequence of the external load (Scanlan, Wen, Tucker, & Dalbo, 2014). **This values could confirm our theory that training sessions have a larger volume and less intensity.**

Conclusions

Due to all of this, we can conclude that the physical and physiological demands during the training of 5c5 are different from those of the official competition in young female players of elite basketball. We find a larger volume of work in training sessions, but the intensities manifested during a match are higher. Therefore, it is needed to reconsider how specific resistance exercises are structured during the basketball training in young female elite players to achieve the most appropriate adaptations with the goal of improve the athletic performance.

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CONTACT

javierespasa12@gmail.com

@JaviEspasa

Anexo III

Control de la carga externa e interna en el baloncesto femenino: revisión sistemática.

Comunicación oral en el III Congreso de la Asociación Española de Preparadores Físicos de Baloncesto, Valencia 2022

Cátedra de baloncesto L'Alqueria del Basket

Universitat de València

asepreb Asociación Española de Preparadores Físicos de Baloncesto

La Cátedra de Baloncesto de la **UNIVERSITAT DE VALÈNCIA** otorga el siguiente certificado a:

Don/Doña **Javier Espasa Labrador**

Por su exposición titulada:

CONTROL DE LA CARGA EXTERNA E INTERNA EN EL BALONCESTO FEMENINO: REVISIÓN SISTEMÁTICA ,

en el *III Congreso Asepreb* celebrado en L´Alqueria del Basket los días 17 y 18 de Junio de 2022.

Joan Ramón Tarragó Costa
Presidente de ASEPREB

ASEPREB Asociación Española Preparadores Físicos de Baloncesto C.I.F.: G-37246435

Dr. D. Ferran Calabuig Moreno
Director de la Cátedra de Baloncesto L'Alqueria del Basket

Pedro Cotolí Suárez
Responsable de L'Alqueria LAB

Fundació València Bàsquet 2000

Anexo IV

Demanda física y respuesta fisiológica en la jugadora de baloncesto.

Aprobación de la solicitud de evaluación de proyecto de investigación por parte del Comité de Ética de Investigaciones Clínicas de la Administración Deportiva de Cataluña

Generalitat de Catalunya
Comitè d'Ètica d'Investigacions Clíniques de l'Administració Esportiva de Catalunya

DR. RAMON BALIUS MATAS,
ACTING AS SECRETARY OF THE ETHICS COMMITTEE
FOR CLINICAL RESEARCH
OF THE CATALAN SPORTS COUNCIL.

CERTIFIES

At the meeting on May 30, 2022, the Ethics Committee agreed to favorably assess the project presented by Azahara Fort, number 013/CEICGC/2022, entitled "Demanda física y respuesta fisiológica en la jugadora de baloncesto".

We note this favorable assessment for the appropriate purposes.

Generalitat de Catalunya
Consell Català de l'Esport
Av. Països Catalans,40-48
08950 Esplugues de Llobregat

Dr. Ramon Balius Matas
Esplugues de Llobregat, May 30, 2022

"El científico encuentra su recompensa en lo que Henri Poincare llama el placer de la comprensión, y no en las posibilidades de aplicación que cualquier descubrimiento pueda conllevar."

Albert Einstein