

UNIVERSIDAD POLITÉCNICA DE MADRID

Facultad de Ciencias de la Actividad Física y del Deporte (INEF)



**PERFORMANCE ANALYSIS IN WOMEN'S
BASKETBALL CONSIDERING GAME-
RELATED STATISTICS, CONTEXTUAL
FACTORS, PHYSICAL INDICATORS, AND
THE MENSTRUAL CYCLE**

DOCTORAL THESIS

Submitted for the degree of Doctor by:

Lorenzo Gasperi

Máster en Ciencias de la Actividad Física y del Deporte

Madrid, 2023



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Doctoral Degree in Sciences of Physical Activity and Sport

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Under the supervision of:

Dr. D. Miguel Ángel Gómez Ruano

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Author: Lorenzo Gasperi

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Thesis Supervision:

Dr. Miguel Ángel Gómez Ruano, Profesor titular en Ciencias de la Actividad Física y
del Deporte, Universidad Politécnica de Madrid (Supervisor)

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To my parents and relatives

To my friends

To my Twin

To Luisa

A mis padres y familiares

A mis amigos

A mi gemelo

A Luisa

Alla mia famiglia

Ai miei amici

Al mio gemellino

A Luisa

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Abstract

Purpose: The importance of understanding the demands encountered during basketball training and gameplay is to improve the game level and qualities of players. The main aim of the PhD thesis is to explore the training and match performance demands of Female basketball players considering game-related statistics, contextual factors, physical indicators, and the menstrual cycle. Specifically, the studies mainly focus on investigating the key performance indicators and collective playing style in European female basketball competitions. The effect of contextual variables (game location, team quality, and opponent quality) was also taken into consideration in the analysis. To implement our purpose, the thesis was driven by the following three research aims. (**Aim 1**) *Firstly*, to examine the differences in game-related statistics and performance between national and foreign basketball players in an elite female competition (EuroLeague), according to playing position and team ability; (**Aim 2**) *secondly*, to investigate the influence of physical and perceptual demands, menstruation-related pain, perceiver recovery and game contextual factors on female basketball players' performances during official competition. (**Aim 3**) *Thirdly*, to understand the impact of the fixture congestion period, through the game-related statics in individual games played in a competitive season, taking into consideration the competition period, the games per week, and the kind of competition in top elite female basketball teams.

Methods: Our analyses used multiple sources of data, including game-related statistics of 112 games from the 2016/2017 season of the Women's EuroLeague (FIBA), the technical and physical performance records from 12 official games during the 2019/2020 competitive season in the Lithuanian and Baltic Female Basketball League and the game-related statistics of a full-season games of all teams (N = 16) participating 225 games in Euroleague Women 2021/2020 season. The methodology was split into 3 main sections focused on each aim, respectively. The first section examine the differences in game-related statistics or performance between national

and foreign female basketball players. Players were categorised based on country of birth versus competition (i.e. foreign or national), playing positions (i.e. Guards, Forwards, Centers), and team ability (i.e. four groups using a cluster of k-means analysis according to the winning percentage of each team during the competition). A structural coefficient (SC) above $|0.30|$ was used to identify the variables that best differentiated the national and foreign players (**Aim 1**). Secondly, 11 professional female players (age: 20.6 ± 2.7 years) were monitored for game-related statistics (Performance Index Rating, PIR; rebounds, REB; effective field goal %, eFG%; turnovers, TO), objective (PlayerLoad per minute, $PL \cdot \text{min}^{-1}$) and subjective (RPE) game loads, perceived recovery (Total Quality Recovery, TQR_{pre}), menstrual phase (follicular; luteal) and game-related contextual factors (game location; game outcome; score differential; opponent level) during 12 official games. Separate linear mixed models evaluated the influence of RPE, $PL \cdot \text{min}^{-1}$, TQR_{pre} , menstrual phase, contextual factors, and individual characteristics (age; playing position) on game-related statistics (**Aim 2**). Lastly, to explain the most important game-related statistics that better allowed differentiating the fixture cycles of 16 teams during a full season of 225 games, a Bivariate Poisson regression model has been proven for modeling basketball games assuming the points scored by each team follows a Poisson distribution, successively to examine the effects of rest day on the final point score of the home and away teams, we extend the bivariate Poisson model to consider rest days (**Aim 3**).

Results: The results of the PhD thesis were described for each specific aim. **Aim 1:** Results showed that foreign players had a better performance according to team ability and playing position for most of the performance indicators with higher values for minutes played, % successful 2-point field-goal, % successful free-throws and % assists. Moreover, foreign players performed better in variables associated with offensive situations while national players were prevailing with indicators associated with defensive actions. **Aim 2:** The results found that higher PIR and eFG% were found for older players and those who reported higher RPE (all

$p < 0.05$). Higher age also led to less TO ($p = 0.042$). eFG% was higher when the player reported higher TQR_{pre} ($p = 0.010$). Better shooting (eFG%) and rebounding (REB) performances were found during the follicular menstrual phase ($p < 0.05$, ESs: small). More REB were collected in won games ($p < 0.05$, ES: small). **Aim 3:** The $\hat{R}$ for all parameters was between 1 and 1.01, indicating the models converged successfully. According to the means of parameters, compared to play after 2 days' rest, the point score of the home team increased along with the increase in the number of rest days (0.016 for 3 days of rest, 0.027 for 4 days of rest, 0.056 for 5 or more days of rest). However, for the visitors, although there was still a higher probability of improvement with 3 and 4 days of rest, after 5 or more days of rest, the final point score of the away team was almost the same as with 2 days of rest.

Conclusions: The discriminatory power of game-related statistics has afforded us valuable insights into the distinctive performances exhibited by national and foreign players, considering their team ability and playing position. Notably, the key findings indicate that foreign players consistently demonstrated higher performance levels in various aspects: (i) they occupied more playing time; (ii) displayed superior shooting proficiency in free-throws and 2-point field-goals across all playing positions; (iii) showcased better teamwork, particularly in terms of assists, among Guard and Forward players; (iv) excelled in securing both defensive rebounds (in the case of Guards) and offensive rebounds (for Centers); and (v) exhibited higher turnover rates, particularly among Forwards (**Aim 1**). Furthermore, the results of Lithuanian and Baltic season revealed three key findings. First, general physical intensity indicators have no significant impact on players' technical performances, emphasizing the need for context-specific assessment of physical demands.

Second, game RPE interpretation should consider individual playing times and game outcomes, which can influence a player's perceived exertion.

Lastly, monitoring menstrual cycle phases in female players can be beneficial. Players tend to

perform better in shooting (eFG%) and rebounding (REB) during the follicular phase. Coaches can adjust tactical plans based on these phases to optimize performance. Additionally, players reporting better recovery (TQRpre) may benefit from last-minute tactical modifications.

(Aim 2). Finally, the study of a full-season in European competition uncovered a non-linear relationship between rest and team performance. Initially, rest has a positive impact on performance, but this effect reaches its peak and starts diminishing as the duration of rest increases. This observation is possibly due to a substantial number of games in both the national league and Euro-league having shorter-than-ideal pre-game rest periods. Over time, players may have adjusted to this congested schedule, and extended rest periods can disrupt their physical rhythms, subsequently affecting their overall game performance. *(Aim 3)*.

Key words: Basketball, Game Performance Analysis, Female European basketball, Game-Related Statistics, Key Performance Indicators, Physical Variables, Menstrual Cycle, Congested Competition.

Resumen

Objetivo: La importancia de entender las demandas que se producen durante el entrenamiento y el partido de baloncesto tienen como objetivo el mejorar el nivel de juego y las cualidades de los jugadores. El objetivo principal de esta tesis doctoral consiste en explorar las demandas de entrenamiento y rendimiento de las jugadoras de baloncesto teniendo en cuenta las estadísticas relacionadas con el juego, los factores contextuales, los indicadores físicos y el ciclo menstrual. Específicamente, los estudios se centran en la investigación de los indicadores clave de rendimiento y el estilo de juego colectivo en la competición europea de baloncesto femenino. El efecto de las variables contextuales (localización del juego, calidad del equipo y calidad del oponente) también se tuvo en cuenta en los análisis. Para implementar el estudio, la tesis se centró en los siguientes tres objetivos de investigación. En primer lugar, examinar las diferencias en las estadísticas relacionadas con el juego y el rendimiento entre los jugadores de baloncesto nacionales y extranjeros en una competición femenina de élite (Euroleague), según la posición de juego y la capacidad del equipo (**Objetivo 1**); en segundo lugar, investigar la influencia de las demandas físicas y perceptuales, el dolor relacionado con la menstruación, la recuperación subjetiva y los factores contextuales del juego en las actuaciones de las jugadoras de baloncesto durante la competición oficial (**objetivo 2**). En tercer lugar, comprender el impacto de la acumulación de partidos, a través de la estadística relacionada con el partido durante una temporada, teniendo en cuenta el período de temporada, los partidos por semana, y el tipo de competición en equipos de élite femenina de baloncesto (**Objetivo 3**).

Métodos: Nuestros análisis utilizaron múltiples fuentes de datos, incluyendo estadísticas de 112 partidos de la temporada 2016/2017 de la Euroliga Femenina (FIBA), los datos de rendimiento técnico y físico de 12 partidos oficiales durante la temporada 2019/2020 en la Liga de Baloncesto Femenina Lituana y Báltica, y las estadísticas relacionadas con los partidos de temporada completa de todos los equipos (N = 16) que participaron en 225 partidos de la

Euroliga Femenina 2021/2020. La metodología se dividió en tres secciones principales centradas en cada objetivo, respectivamente. La primera sección examina las diferencias en las estadísticas relacionadas con el juego o el rendimiento entre las jugadoras de baloncesto nacionales y extranjeras. Los jugadores se clasificaron en función del país de nacimiento (es decir, extranjeros o nacionales), las posiciones de juego (es decir: bases, aleros, y pivots) y el nivel del equipo (p. ej., cuatro grupos que utilizan un clúster de análisis de k-medias según el porcentaje de victorias de cada equipo durante la competición). Se utilizó un coeficiente estandarizado superior a $|0.30|$ para identificar las variables que mejor diferenciaban a los jugadores nacionales y extranjeros (**Objetivo 1**). En segundo lugar, 11 jugadoras profesionales (edad: 20.6 ± 2.7 años) fueron monitoreadas por estadísticas relacionadas con el juego (Performance Index Rating, PIR; rebotes, REB; canstas de campo efectivo %, eFG%; pérdidas de balón, TO), cargas de juego objetiva (PlayerLoad por minuto, $PL * \text{min}^{-1}$) y subjetiva (RPE), recuperación percibida (Total Quality Recovery, TQRpre), fase menstrual (folicular; lútea) y factores contextuales relacionados con el partido (localización del partido; resultado del partido; diferencial de puntos; nivel del oponente) durante 12 partidos oficiales. Se realizaron modelos lineales mixtos separados para evaluar la influencia de RPE, $PL * \text{min}^{-1}$, TQRpre, fase menstrual, factores contextuales y características individuales (edad; posición de juego) en las estadísticas relacionadas con el juego (**Objetivo 2**). El último objetivo se centra en explicar las estadísticas más importantes relacionadas con el partido que permiten diferenciar mejor los tipos de semana de 16 equipos durante una temporada de 225 partidos. Para ello, se realizó un modelo de regresión Bivariate Poisson tratando de modelar los partidos de baloncesto suponiendo que los puntos anotados por cada equipo siguen una distribución de Poisson, de modo que se puedan examinar los efectos del día de descanso en el marcador final de los equipos cuando juegan en casa y fuera, asimismo se adaptó el modelo bivariado de Poisson para controlar los días de descanso dentro de la semana analizada (**Objetivo 3**).

Resultados: Objetivo 1: Los resultados mostraron que las jugadoras extranjeras tenían un mejor rendimiento según el nivel del equipo y la posición de juego para la mayoría de los indicadores de rendimiento con valores más altos para los minutos jugados, % tiros de campo anotados de 2 puntos, % tiros libres anotados y % asistencias. Además, los jugadores extranjeros tuvieron un mejor rendimiento en las variables asociadas con situaciones ofensivas, mientras que los jugadores nacionales prevalecieron con los indicadores asociados con las acciones defensivas.

Objetivo 2: Los resultados encontraron un mayor PIR y eFG% para jugadores de mayor edad y aquellos que reportaron un mayor RPE (todos $p < 0.05$). Una mayor edad también condujo a menos TO ($p = 0.042$). El eFG% fue mayor cuando el jugador reportó TQRpre más alto ($p = 0.010$). Se encontraron mejores resultados de tiro (eFG%) y rebote (REB) durante la fase folicular menstrual ($p < 0.05$, ESs: pequeño). Asimismo, se observaron más REB en juegos ganados ($p < 0.05$, ES: pequeño). **Objetivo 3:** Los resultados de los modelos de regresión mostraron valores de R para todos los parámetros entre 1 y 1.01, lo que indica que los modelos fueron robustos. De acuerdo con los parámetros de análisis, en comparación con el partido disputado después de 2 días de descanso, la puntuación del equipo local aumentó junto con el aumento en el número de días de descanso (0.016 puntos para 3 días de descanso, 0.027 puntos para 4 días de descanso, 0.056 puntos para 5 o más días de descanso). Sin embargo, para los equipos visitantes, se encontró que había una probabilidad de mejora con 3 y 4 días de descanso, después de 5 o más días de descanso, aunque el puntaje final del equipo visitante fue casi el mismo que con 2 días de descanso.

Conclusiones: El poder discriminatorio de las estadísticas de juego ha proporcionado información valiosa sobre las actuaciones distintivas exhibidas por las jugadoras nacionales y extranjeras, teniendo en cuenta el nivel del equipo y la posición de juego. En particular, los hallazgos clave indican que las jugadoras extranjeras demostraron consistentemente niveles de rendimiento más altos en varios aspectos: (i) más minutos de juego; (ii) rendimiento superior

en tiros libres y lanzamientos de 2 puntos anotados en todas las posiciones de juego; (iii) un mejor trabajo en equipo, particularmente en términos de asistencias, entre los jugadores de bases y aleros; (iv) destacaron en rebotes defensivos (en el caso de bases) y rebotes ofensivos (para pivots); y (v) exhibieron mayores tasas de rotación, particularmente en los aleros (*Objetivo 1*).

Por otro lado, los resultados de la temporada Lituana y Báltica revelaron tres hallazgos clave. En primer lugar, los indicadores generales de intensidad física no tienen un impacto significativo en el desempeño técnico de los jugadores, haciendo hincapié en la necesidad de una evaluación de las demandas físicas específicas del contexto (tipo de semana).

En segundo lugar, la interpretación RPE del juego debe considerar los tiempos de juego individuales y los resultados del partido, que pueden influir en el esfuerzo percibido de un jugador.

Por último, el seguimiento de las fases del ciclo menstrual en las jugadoras puede ser beneficioso. Las jugadoras tienden a tener un mejor desempeño en tiro (eFG%) y rebote (REB) durante la fase folicular. Los entrenadores pueden ajustar los planes tácticos basados en estas fases para optimizar el rendimiento. Además, las jugadoras que reportan una mejor recuperación (TQRpre) pueden beneficiarse de modificaciones tácticas de último minuto (*Objetivo 2*).

Por último, el estudio de una temporada completa en la competición europea (Euroleague) reveló una relación no lineal entre el descanso y el rendimiento del equipo. Inicialmente, el descanso tiene un impacto positivo en el rendimiento, pero este efecto alcanza su punto máximo y comienza a disminuir a medida que aumenta la duración del descanso. Esta observación se debe posiblemente a un número sustancial de partidos tanto en la liga nacional como en la Euroliga que tienen períodos de descanso previos al partido más cortos que los que serían deseables. Con el tiempo, los jugadores pueden haberse ajustado a este calendario

congestionado, y los períodos de descanso prolongados pueden interrumpir sus ritmos físicos, afectando posteriormente en su rendimiento general del partido (***Objetivo 3***).

Palabras clave: Baloncesto, Análisis de rendimiento, Baloncesto europeo femenino, Estadísticas relacionadas con el juego, Indicadores clave de rendimiento, Variables físicas, Ciclo menstrual, Partidos congestionados.

Declaration

I, Lorenzo Gasperi, declare that the Doctor of Philosophy thesis entitled “Performance analysis in women's basketball considering game-related statistics, contextual factors, physical indicators, and the menstrual cycle.” is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes. This PhD. thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature:

Date:

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List of Abbreviations

%HRmax. percentage of maximal Heart Rate

2 ptA. Two-point Attempted

2 ptM. Two-point Made

3 ptA. Three-point Attempted

3 ptM. Three-point Made

ACB. Asociación de Clubs de Baloncesto

ACWR. Acute:Chronic Workload Ratio

AST. Assists

AU. Arbitrary Units

BLK. Blocks

DREB. Defensive Rebounds

FTA. Free throws Attempted

FTM. Free throws Made

GRS. Game-Related Statistics

HA. Home Advantage

KPI. Key performance indicators

LCB. Liga Portuguesa de Basquetebol

ME. Mental Effort

MF. Mental Fatigue

NBA. National Basketball Association

OREB. Offensive Rebounds

PF. Personal Fouls

PIR. Performance Index Rating

PL. PlayerLoad

RPE. Rating of Perceived Exertion

SD. Standard Deviation

SE. Standard Error

sRPE. session Rating of Perceived Exertion

SSG. Small-Sided Game

STL. Steals

TL. Training Load

TOV. Turnovers

TQR. Total Quality Recovery

TREB. Total Rebounds

USA. United States of America

VAS. Visual Analogue Scale

WNBA. Women's National Basketball Association

D. Lorenzo Gasperi

CHAPTER 1

Introduction

Chapter 1 introduction

1.1 General introduction

The history of basketball and women's basketball is a fascinating story of innovation and adaptation. James Naismith's invention of basketball in 1891 marked the birth of the sport, but it was Senda Berenson, a Canadian physical education teacher, who played a pivotal role in adapting the game for women and transforming it into a legitimate sport.

Senda Berenson recognized the potential of basketball as a form of physical activity for women, but she also understood that it needed to be modified to suit the physical capabilities and social norms of the time. In 1892, she adapted the rules of basketball, making it less physically demanding and more suitable for women. Her modifications included reducing the physical contact in the game and introducing rules that encouraged more controlled and less strenuous play.

Berenson's efforts went beyond just adapting the rules. She also advocated for women's participation in sports, including basketball, as a means of promoting physical fitness and overall well-being. Her work helped break down gender barriers in sports and contributed to the acceptance of women's basketball as a legitimate athletic pursuit.

One key distinction between women's basketball and men's basketball during this early period was that women's basketball was seen as a sport from the outset, whereas men's basketball initially had a more recreational or activity-oriented focus. Women's basketball provided an opportunity for women to engage in competitive sports, which was groundbreaking for its time.

The history of women's basketball is a testament to the dedication and vision of individuals like Senda Berenson, who recognized the importance of adapting sports to make them inclusive and

accessible to all, regardless of gender. Today, women's basketball has evolved into a thriving and highly competitive sport with a rich history and a global following, thanks to the pioneering efforts of Berenson and others who followed in her footsteps (Myerscough, 2007).

The history of basketball is intricately linked to the societal changes and evolving perceptions of gender roles during the late 19th and early 20th centuries. During the Victorian era, the prevailing cultural norms and expectations for women were quite different from those of men, and this influenced how sports like basketball were initially played by women.

In the 19th century, physical activity for women was often discouraged or limited to activities considered suitable for the Victorian ideal of femininity, which included a focus on modesty and decorum. This mindset was reflected in the early rules and attire of women's basketball.

The division of the basketball court into three parts and the use of nine players per team were adaptations aimed at making the game less physically demanding and more in line with the perceived capabilities of women at the time. Additionally, the long, floor-length dresses that women wore during early games were consistent with the modest clothing expectations of the era. These dresses covered the entire body, with only the hands and face exposed. The introduction of bloomers in 1896 marked a significant shift in women's basketball attire. Bloomers were more practical for sports, allowing greater freedom of movement and reducing the risk of accidents caused by long, flowing dresses. This change was not only a matter of convenience but also symbolic of the evolving attitudes towards women in sports. It signified a move towards recognizing that women could engage in physical activity in a manner that was both comfortable and safe while challenging traditional notions of femininity. The transformation of women's basketball attire and rules over time reflects broader social changes and a growing acceptance of women's participation in sports. It was part of a larger movement towards gender equality in sports and society at large. Today, women's basketball is a highly

competitive and physically demanding sport, and it has come a long way from its early days when it was played in long dresses with modified rules to accommodate societal expectations. The evolution of women's basketball reflects the progress made in breaking down gender barriers and promoting equality in sports (WNBA.com - Official Site of the WNBA, 2022).

Since those days, basketball has evolved incredibly, becoming one of the most followed and practiced sports in the world (Hulteen et al., 2017). Indeed, the journey of women's basketball to attain equal recognition and opportunities has been a gradual one. It wasn't until 1976 that women's basketball was officially included in the Olympic Games, marking a significant milestone in its history. The subsequent year, in 1977, witnessed another pivotal moment when women's basketball games began to be played on the same court as men's games, a symbolic move towards parity in the sport.

As women's basketball continued to gain traction, some differences emerged in comparison to men's basketball. These distinctions often centered on factors that considered the physiological and playing style differences between male and female athletes. For instance, the size of the basketball used in women's games is slightly smaller than that used in men's game. Additionally, the introduction of the 3-point line was a notable variation, altering the strategic dynamics of the game. Nevertheless, the core essence of basketball remained the same for both men and women. It is a dynamic and fast-paced team sport played by two teams, each consisting of five players on the court at a time. The objective is to outscore the opposing team by shooting the basketball through the opponent's hoop. In Europe the game is typically divided into four quarters, each lasting 10 minutes, resulting in a total playing time of 40 minutes.

The basketball court itself is a standardized size in Europe, measuring 28 meters in length and 15 meters in width, with two baskets positioned at opposite ends of the court. These baskets

serve as the scoring targets for each team, and the game's fundamental challenge lies in both defending one's own basket and scoring in the opponents. Despite the minor variations that exist, the fundamental principles of teamwork, strategy, skill, and athleticism are universal in basketball, transcending gender differences. Over time, women's basketball has continued to grow in popularity and visibility, and it has become an integral part of the global sports landscape, with female players making their mark as elite athletes and role models.

Several competitions are organized every year, we can recognize the most important in USA, the WNBA, and, a part domestic league of each country, Women EuroLeague and Women EuroCup in the old continent. The growing interest in this sport has meant that the competitive level has increased and, consequently, the importance of the result (Gregg & Gregg, 2017).

In order to attain a high level of success in the realm of female basketball, it is vital that both coaches and players commit themselves to the meticulous development of comprehensive training programs that are specifically tailored to their needs. These programs serve as the foundation upon which their match preparation is constructed, allowing them to refine their strategies and gameplay tactics well ahead of each competition. Furthermore, it is essential for players to not only possess a deep understanding of these strategies but also to effectively apply the right tactics with precision and adaptability during the dynamic and unpredictable course of the match. In this multifaceted process, achieving success becomes a worthy and relentless pursuit (Zarić et al., 2021).

The sporting event is studied and researched from many angles. The application of scientific methods to sports permit to study training and game and its effects on humans' performance, scientists and coaches gain the information they need to design training programs that ensure the health and performance for athletes. In this context it is important to measure the performance of players in training and competition and the results of the training process (Foster

et al., 2017).

Within the realm of sports, a diverse options of training methodologies are utilized to enhance the physical and technical skill of athletes, with basketball being no exception. In the pursuit of elevating their performance, practitioners of this sport commonly employ a spectrum of training techniques, each designed to cater to distinct facets of an athlete's development.

First of all, the game-based conditioning emerges as a foundational pillar of basketball training. It is through meticulously designed game simulations and scenarios that players cultivate their on-court skills, allowing them to adapt swiftly to the dynamic nature of actual matches.

Metabolic conditioning, another integral component, focuses on enhancing the athletes' overall resistance and endurance, ensuring they possess the requisite physical fortitude to excel during intense competitions. Agility training, a critical facet of this multifaceted approach, refines players' agility, speed, and change of direction, equipping them with the agility to navigate swiftly through the court's various demands. Strength training, on the other hand, is pivotal for cultivating the muscular power essential for explosive plays and enduring physical fights. Simultaneously, skill training is indispensable in honing an athlete's technical abilities, fostering their proficiency in shooting, dribbling, passing, and defensive situation.

Furthermore, an in-depth analysis of game-related statistics assumes a prominent role in training programs, allowing for personalized development plans that are finely attuned to the strengths and weaknesses of individual players.

In the confluence of these diverse training methodologies, the KPI for success in female basketball, emerges a comprehensive and multifaceted approach that elevates athletes to their maximum possibilities (Sampaio et al., 2006; Stojanović et al., 2018).

Considering these practical issues and the need for objective and unbiased feedback athlete performance analysis can then be used to gather accurate and reliable valuable knowledge in the competitive environment to improve athletic performance (O'Donoghue, 2014).

The following section provides an overview of game-related statistics and workload monitoring in basketball players, especially regarding female athletes.

1.2 Game-Related Statistics in Basketball, an overview

The game-related statistics in basketball has been studied in many aspects, different competitive levels and for both male and female players. The ready accessibility of these statistics on the Internet has been a transformative force in advancing scientific research dedicated to the analysis of sports games. Over the span of more than two decades, this transformative influence has been especially pronounced within the basketball domain, surpassing other sporting disciplines in its depth and breadth of statistical analysis.

This evolution has been fuelled by a collaborative synergy between coaches and scientists, working in concert to elevate the utility and precision of game-related statistics. Their concerted efforts have resulted in substantial enhancements across various facets of both training and competition.

Within the realm of training, the infusion of advanced statistical insights has empowered coaches and athletes to develop more finely tuned and effective training regimens. These regimens are meticulously designed to target specific areas of improvement, ensuring that players are equipped with the skills and strategies needed to excel on the court. In the crucible of competition, these enhanced game-related statistics serve as a marker, guiding teams and athletes towards superior performance and more favourable outcomes. With a comprehensive understanding of their strengths and weaknesses, competitors can strategically adapt their game

plans, make real-time adjustments, and exploit opponents' vulnerabilities with precision. As the connection of statistics and basketball continues to evolve, it consolidates a new era of scientific investigation, lighting innovative approaches to understanding the sport. In this dynamic landscape, the interplay between accessible data and non-stop pursuit of improvement promises to shape the future of basketball, elevating performance, and results to unprecedented heights.

In their quest to discern disparities and evaluate the influence of home-court advantage, Pollard and Gómez (2015) undertook an extensive examination of various college and professional matches within the United States' sports leagues. Their methodology involved assessing the projected number of victories achieved on home turf, expressed as a percentage relative to the total number of games played, both home and away. Across the spectrum of college and professional sports, their analysis unearthed a compelling pattern: a pronounced and statistically significant domestic advantage spanning a range from 54.85% in the realm of professional baseball to a commanding 66.61% within the domain of college basketball.

An interesting facet of their research is the conspicuous variation in home-court advantage across distinct levels of competition. Notably, basketball emerges as the sport with the most notable disparity, exhibiting a marked contrast of 6.75 percentage points between college and professional levels. College basketball, with its impressive 66.61% home-court advantage, distinctly outshines its professional counterpart, which boasts a still formidable 59.86%. This profound difference underscores the profound impact of the home-court advantage phenomenon within the collegiate basketball arena, offering a captivating focal point for further investigation and analysis in the realm of sports science (Pollard & Gomez, 2015).

Game-related statistics offer a valuable means to gain a more comprehensive comprehension of the phenomenon known as home-court advantage. This advantage can be illuminated through

the examination of several factors grouped under the overarching category of "effects on the crowd". These include the influence of the enthusiastic audience, potential referee biases, the impact of travel on teams, the significance of domestic conditions, the support provided by players' families, and the psychological and behavioural dynamics inherent to the local playing environment. Through statistical analysis, we can delve into these multifaceted elements and uncover the intricate mechanisms that contribute to the pronounced advantage experienced by home teams in sports (Sors et al., 2020).

Sampaio and colleagues (Sampaio et al., 2007) conducted a comprehensive study on individual player performance, specifically focusing on the discriminant power of game-related statistics within the context of clustered player positions: guards, forwards, and centres across three distinct basketball leagues, namely the NBA, ACB, and LCB. Their investigation included a range of the most commonly used variables, including 2- and 3-point field-goals (both successful and unsuccessful), free-throws (both successful and unsuccessful), defensive and offensive rebounds, blocks, assists, fouls, steals, turnovers, and minutes played.

This research serves to underscore the critical importance of comprehending the unique contributions of individual players to their respective teams. For instance, the study illuminated that in the Portugal league, centres hold a prominent role due to their physical presence and their invaluable contributions in the defensive phase of the game. In contrast, the ACB league exhibited a more homogenized profile among players, suggesting a greater degree of interchangeability in their roles. This insight challenges the notion of players having distinct, specialized roles. Notably, within the NBA, disparities in player positions were particularly pronounced. However, the researchers attributed these discrepancies to differences in league rules, such as the greater distance of the 3-point line compared to European basketball. This emphasizes the importance of contextual factors in understanding player roles and performance.

The outcomes of this study represent a valuable addition to our understanding of the intricate dynamics of basketball. By delineating the distinct behaviours of players in accordance with their positions, it offers valuable insights into how team performance hinges on the complementary abilities of its players. In essence, this research deepens our appreciation of the multifaceted interplay between individual player characteristics and team dynamics within the realm of basketball.

The research group lead to Sampaio extended their investigations to explore the dominance of the United States during the Olympic Games in Beijing (Sampaio et al., 2010). Their findings unveiled a significant emphasis on defensive prowess, characterized by a notable increase in the retrieval of possession, and a prevailing preference for two-point field goals in offensive situation.

Interestingly, when opposing teams sought to elevate the tempo and intensity of the game, their efforts primarily manifested in an escalation of fouls committed. Furthermore, regarding the defensive intensity, the researchers observed a heightened level of activity during the initial stages of the game. This temporal pattern indicated that teams were more vigorous in their defensive efforts during the early phases, possibly as part of a strategic approach to establish control and thwart the opposing team's momentum.

Sampaio and their colleagues' analysis shed light on the distinctive strategies employed by the dominant United States team during the Beijing Olympics. Their work underscored the pivotal role of defence, a preference for two-point field goals in offense, and provided insights into how the intensity of the game varied throughout its duration. These findings contribute to a deeper understanding of the dynamics at play in high-stakes international basketball competitions (Sampaio et al., 2010).

In the same year, another noteworthy study conducted by a research team led by Sampaio sought to discern variations in the performance of Spanish male basketball players, with a particular focus on factors such as team quality and playing time (Sampaio et al., 2010). To achieve this, the researchers employed a comprehensive analysis of game-related statistics for each player within different league clusters categorized as high, medium, and low levels, as well as classifying players into high and low ability groups.

The study yielded compelling insights into the relationship between team quality and game-related statistics (GRS). The results indicated a strong correlation between the quality of the team and most GRS variables, with the notable exceptions being free-throws, offensive rebounds, and errors. Teams of higher quality consistently outperformed their counterparts in all other statistical categories, followed by intermediate-level teams, and finally, weaker teams. This observation underscored the influence of team dynamics and quality on player performance.

Furthermore, when considering player quality, offensive variables such as 2- and 3-point field goals, passing, offensive rebounds, and free-throws emerged as the most pivotal factors. These variables were identified as the primary indicators of a player's significance within their team. Players who excelled in these areas tended to hold greater importance to their respective teams, with the exception of offensive rebounds.

The study also revealed disparities between less important players across strong, moderate, and weak teams, as well as disparities between important players in strong and weak teams. This finding suggested that an athlete's playing time is influenced not only by their scoring prowess, including free throws and field goal shots, and their passing abilities but also by the errors they make during competitive play. This multifaceted analysis offers a nuanced perspective on the intricate interplay between team quality, player ability, and playing time allocation in the realm

of Spanish male basketball.

These performance profiles remained consistent across seasons, indicating a lack of significant seasonal variations in peak basketball performance. Furthermore, the study revealed that the overall ranking system was highly effective in differentiating and scoring the best-performing teams, but it didn't effectively distinguish between average and weaker teams. While it was evident that stronger teams consistently outperformed others, the distinguishing factor for intermediate and weaker teams was primarily related to defensive rebounds.

In a related study published by Sampaio and Janeira (2003), the research delved into the dynamics of balanced and unbalanced games. In balanced contests, where the outcome was closely contested, the losing team displayed inferior performance across all game-related statistics compared to the winning team. Additionally, during the regular season, the margin of victory was relatively narrower than in playoff matches.

Interestingly, the winning team tended to commit fewer fouls, register fewer successful 2-point field goals, and accumulate more successful free-throws than their losing counterparts.

The discrimination between winning and losing teams extended to away matches as well. In these scenarios, the winning team was characterized by a notable advantage, scoring three more successful free-throws and securing more defensive rebounds compared to the losing team.

Notably, when examining game-related statistics during home playoff matches, distinctions between the winning and losing teams were also apparent. The winning team committed fewer fouls, while the losing team exhibited a deficiency in offensive rebounds. Furthermore, the winning team's performance was notably enhanced by their proficiency in free-throws.

These findings collectively provide valuable insights into the intricate dynamics of basketball

performance, illuminating on how various game-related statistics can be indicative of success and differentiation between teams in different game scenarios (Sampaio & Janeira, 2003).

Csataljay's study (2009), provides additional support for the thesis put forth by Sampaio and Janeira regarding the critical performance indicators that differentiate winning and losing teams in the context of basketball. Notably, the study findings reaffirm the significance of certain key factors, with a particular emphasis on the 3-point shooting percentage, the number of successful free throws, and defensive rebounds. These indicators were found to hold relevance across various levels of play, whether it be home or away games, as well as during different phases of the season, such as the regular season or playoffs. In close games where the final score exhibited a narrow difference, typically between 1 and 9 points, Csataljay's research highlighted the percentage of successful free throws and a substantial number of defensive rebounds as the primary indicators that set apart winning teams from their losing counterparts. These statistics proved to be pivotal in determining the outcome of closely contested matches. In the context of balanced games, reinforced the vital significance of shooting percentages, both in terms of 2-point and 3-point shots. These shooting percentages emerged as the key variables distinguishing performance levels in games where the competition was closely matched.

Csataljay's research findings align with Sampaio and Janeira's assertions, underscoring the critical role played by specific performance metrics in identifying successful basketball teams. In a separate study focused on Spanish men's professional basketball (Gómez et al., 2008), researchers delved into the disparities between winning and losing teams, with an emphasis on the final game outcome. This study revealed intriguing findings, particularly with regard to balanced and unbalanced games.

In the context of closely contested, balanced games, the statistics that emerged as the most distinguishing factors between the two groups were predominantly offensive in nature.

Specifically, successful 2-point and 3-point field-goals, unsuccessful 3-point field-goals, assists, steals, turnovers, and fouls played pivotal roles in differentiating winning and losing teams. These offensive statistics highlighted the importance of offensive efficiency and playmaking prowess in closely matched encounters.

Conversely, in games characterized by a substantial disparity in score, the study pointed to different key statistics. In such unbalanced games, the variables that had the most pronounced impact on the outcome were the number of unsuccessful free-throws and defensive rebounds. This shift in emphasis between balanced and unbalanced games suggests that player evolution may contribute to these changes. Additionally, other contextual factors, such as the frequency and pace of the game played by the team, may also play a role in shaping the significance of these statistics.

Ibañez and his research group conducted an interesting study of young basketball players to determine the variation in game statistics that differentiate between winning and losing basketball teams in consecutive games (Ibañez et al., 2009). Indeed, the research conducted by Ibañez and their group shed light on a crucial observation: the discriminant game-related statistics (GRS) can vary significantly depending on the specific context of the game. Their findings indicate that the performance indicators that distinguish winning teams from losing ones in regular season matches may differ from those in playoff games (Sampaio & Janeira, 2003). For instance, the role of free-throws (Christoforidis, 2000) as a key differentiator in game outcomes can be context-dependent, underlining the importance of considering the unique dynamics and circumstances surrounding each game when analysing performance statistics. The study by Ibañez and their research group drew data from a substantial sample of 223 games in the Under-20 Spanish league, spanning the 2005/06 and 2006/07 seasons. Their analysis yielded noteworthy results, revealing distinct patterns in game-related statistics (GRS) between

winning and losing teams.

Across the games examined, it became evident that the winning teams generally outperformed their opponents in the majority of the key GRS categories. However, there were exceptions to this trend, particularly concerning 3-point field goals, free-throws missed, and turnovers. Interestingly, the sole difference observed was a reduction in turnovers for both winning and losing teams as they progressed from the second to the third consecutive game. This decrease in turnovers between the second and third games could potentially be indicative of several factors. One plausible explanation is that the team's performance over three consecutive games was remarkably consistent, suggesting that accumulated fatigue may have started to impact overall team performance. Additionally, it's conceivable that players, recognizing the significance of the final match for their tournament ranking, took special precautions to minimize turnovers, leading to this observed decrease.

Overall, these findings underscore the intricate dynamics at play in basketball, where a multitude of variables, including fatigue and situational importance, can influence player and team performance. The study by Ibañez and their group provides valuable insights into the nuanced nature of basketball competitions, particularly at the youth level.

A more recent study conducted by Zhang (2017) aimed to assess the technical and physical performance of basketball players based on their playing positions within both strong and weak teams during the NBA regular season (Zhang et al., 2017). The research brought to light intriguing insights into how player performance varied according to team strength and position.

One significant observation was that players from stronger teams tended to cover shorter distances on the court, even moving at slower speeds, in comparison to players from weaker teams. This finding underscores the notion that stronger players are more efficient in their

movements, potentially due to a superior understanding of game strategy and positioning.

Furthermore, the study revealed correlations between physical variables and game style, as well as game-related statistics (GRS). Notably, players from both strong and weak teams exhibited improved performance in steals and 2-point field-goals. However, this improvement was particularly pronounced when analysed by specific player positions.

In the case of guards from the strongest teams, they excelled in free-throws, both in terms of successful attempts made and overall attempts. These players also demonstrated a reduced running distance and speed compared to their counterparts in weaker teams, suggesting a more controlled and efficient style of play. Forwards and centres stood out in their 3-point shot attempts, particularly among players from weaker teams. Interestingly, players in these positions on weaker teams displayed higher values in successful 2-point shots made and attempted, potentially indicating a different offensive strategy employed by these teams. Among centres from weaker teams, there was a notable increase in turnovers and assists. This variation in performance could be attributed to a distinct utilization of their skills and characteristics compared to centres playing for stronger teams (Zhang et al., 2017).

In another noteworthy study conducted by Sampaio and their colleagues, the significance of home advantage in the Euroleague season was explored (Sampaio et al., 2008). The study revealed a striking trend where home teams emerged victorious in a substantial portion of the games, winning up to 66% of the matches. This observation underscored the potent influence of playing on one's home court in European basketball competitions. A particularly intriguing finding of the study was the identification of a significant interaction effect between game location (home or away) and playing position. This interaction effect suggests that the impact of home advantage varies depending on the specific position played by the athletes. In other

words, the advantage conferred by playing at home has a differing degree of influence on players in distinct positions, adding complexity to the understanding of how game location affects performance in the Euroleague.

Regarding playing position, the results of a study in home and away games revealed intriguing differences in player performance based on their roles on the court (García et al., 2017). Notably, guards displayed variations in defensive rebounds, assists, and fouls between home and away matches, suggesting that the playing environment influences their contributions. Forwards, on the other hand, exhibited differences in free-throws scored, steals, blocks, and fouls committed based on game location, highlighting the distinct performance dynamics of players in this position. Interestingly, centres showed relatively consistent performance across both types of games, with similar game-related statistics in home and away matches.

These disparities in player statistics based on position could be attributed to several factors. One plausible explanation is the impact of player anthropometric traits, which can influence their positioning on the court. Players with different physical characteristics may naturally find themselves playing at varying distances from the basket, affecting their roles and contributions. Additionally, it is conceivable that playing different positions in basketball demands distinct psychological characteristics and specific developmental traits honed through practice and competition. These psychological and developmental factors may contribute to the variations in player performance based on their roles on the court. In a more recent study conducted in 2017, the importance of home advantage in male professional ACB was found to be slightly lower at 55.2%. Nevertheless, even with this reduced percentage, the study highlighted the continued significance of the defensive phase of the game, particularly the importance of defensive rebounds. This finding underscores the enduring impact of defensive play on game outcomes in professional basketball, even in a league with a somewhat reduced home

advantage.

Overall, these studies provide valuable insights into the intricate interplay of playing positions, home advantage, and player performance in basketball. They underscore the multifaceted nature of the sport and the diverse factors that contribute to the dynamics on the court (García et al., 2017).

1.3 Game-Related Statistics in female Basketball

Although research in women's basketball is reduced compared to that produced for the male gender, the number of jobs and interest is increasing in recent years (Conte & Lukonaitiene, 2018).

Notational analysis and game statistics increasingly represent a fundamental point in the preparation of matches by the coaching staff and thanks to the ease in finding data and information, is becoming a common practice at all levels to identify the variables that best describe the game: individual characteristics, the areas of the field with better shooting percentages, The importance of factors external to the game and the performance related to the playing positions are just some of the many variables considered during the season (Eaves, 2015).

The increased interest in sport and in particular women's basketball, allows us to have more information from the world of research and be able to better understand these aspects for a specific population.

1.3.1 Physical and anthropometric aspects

Recent research has focused on the correlation between physical characteristics, functional capabilities, and competitive performance.

The work of Paulauskas and Balčiūnas in the Lithuanian league has shown that the shooting percentage has an important effect on the outcome of the match and is a game statistic related to the player's body mass (Paulauskas et al., 2011). Especially in areas of the field close to the basket, where physical contact with the opponent is constant, a greater body mass allows for better results, well as in the jump shoot it was seen how the duration of the jump affects the chances of scoring and a better jumping ability positively affects the percentages on the 2-point shot.

On the contrary, for the 3-point shots no correlation was observed with the fitness indicators examined, while the 2-point shots are closer to the opponents and require greater jumping abilities, in 3 shots the player is in conditions where the jump is not a discriminated on the percentage of achievement. The same reasoning applies to free throws, since made from a controlled position and without physical disturbances, the values of jump and strength in the lower limbs are not related to the positive result of the shot, probably psychological and stress factors, in addition to the shooting technique and the result of the game more influence this type of shooting (Kozar et al., 1994).

The rebound is another variable that seem to be well related to the body mass of the players, this is because a greater muscle mass and body allows to fight better under the basket, gaining positions more favourable to the rebound. Another parameter that has been observed in rebounds is the psychomotor response time, this value affects since a rapid movement towards the ball allows to have an advantage against the opponent fighting for the rebound, although other factors contribute to the success of the action, such as the position under the basket, but

also anaerobic a lactic muscular power. The ability to express intense force continuously for several seconds, typical of contact under the basket is an important factor, which allows you to perform specific movements of basketball, such as changes of direction, thrusts and box-out. The rebound analysis then concludes with two variables that do not have a strong correlation with it: the height of the jump and the height of the player. It is reasonable to think that the other variables observed, such as body mass and muscle work ability, are, for the Lithuanian competition, more important factors to conquer rebounds under the basket (Paulauskas et al., 2011).

As for personal faults, there is a correlation with the speed of muscle contraction, this is because the phallus is not a variable with high technical content-tactic and a player with better muscle contraction potential will be able to defend more successfully avoiding personal fouls. This action requires less technical and tactical training and has a strong link with the intensity and motivation that the player exerts to create pressure on the opposing player (Sampaio & Janeira, 2003).

In contrast, the number of passes performed by a player is not correlated with fitness indicators and physical ability, probably due to finer components of skill in the game of basketball such as the field of view, the perception of space and companions and the ability to anticipate opposing movements. The same is true for the number of turnovers and steals, where no relationship has been observed with the physical abilities of the players, probably being abilities that require more technical-tactical than the physical (Lidor & Arnon, 2000).

Different results compared to the previous ones were found regarding the height of the players and the blocks, the correlative analysis showed that this type of variable is technically simple and with a link to the height, unlike the rebounds (Paulauskas et al., 2011).

Another important work on fitness assessment and body characteristics related to performance

factors during the match was conducted by the Spanish research group in 2021 (Triguero et al., 2021). Fitness assessment allows us to get information about the player's abilities at that time of the season and to make adjustments to the training program depending on the position of the game.

Triguero and colleagues (2021) analysed the main game statistics related to seven fitness and physical variables: i) Technical-tactical efficacy; ii) % Maximum Heart Rate (%HRMax); iii) Distance travelled (m); iv) Distance travelled at high intensity (m); v) Jump time (ms); vi) Jump height (cm) and vii) Impulse in G-Force. As for the relationship between these physical variables and game statistics, the results confirmed the relationship between all factors. This leads to thinking that fitness matters during the game.

In the anaerobic ability test, it was observed that the players who travelled the most distance and were able to express explosiveness were also those who got the most shots from 3 points, while getting less free throws and rebounds during competitions. These results allow us to understand that perimeter players have the greatest distances covered during a race (Puente et al., 2017).

As for rebounds, they are inversely related to the distances covered during competitions, this explains that bigger and physically strong players are closer to the basket, than fast and explosive players. Players who struggle in the paint zone for a rebound are also subject to numerous fouls that result in free throws.

This is a data that coincides with previous research (Ibáñez et al., 2015) and, similarly in the study of Macha-Triguero, the players who have covered a greater distance during the anaerobic test have obtained the least number of blocks during the competition (Triguero et al., 2021). This may be due to the fact that players who make fewer blocks during the season have a position further away from the paint-zone. In areas far from the basket, the number of blocks is

smaller than in nearby areas where the defence is in close contact (Delextrat et al., 2015).

The study of Triguero and colleagues also took into consideration the disposition on the field of the players, highlighting how those who played in perimeter areas also had better results in speed tests, lower rebounds and a lower heart rate. On the contrary, the players who participated more in the areas near the basket have less movement and usually a more static game and had higher strength values, with a higher number of rebounds obtained and do not travel long distances during a match (Román et al., 2019). In addition, these players tend to be characterized by high technical and tactical control during matches which make the athlete sometimes take excessive risks, which can lead to technical errors (turnover, steal, travel, pass bad) (Ibañez et al., 2018).

1.3.2 Playing position

A limited number of studies documented the difference of game-related statistics considering the playing positions.

The available studies have identified the differences of female basketball players considering playing positions from anthropometric, physical, physiological and biomechanical perspectives (Delextrat et al., 2015; Kucsa & Mačura, 2015; Power et al., 2022).

In 2020, the team led by Zongpeng Zhai (2020), produced an analysis on differences performance between players from different continents, considering the playing position (Zhai et al., 2020). 471 matches were observed over a 4-year period in the America, Africa, Asia and Europe Championships. As for the results of the inter-centre analysis, it has been observed that the African centres perform less two-point made and 2Pta than the European and Asian centres, while the American centres are capable of taking more defensive rebounds than the European centres, showing a greater athletic ability of the players participating in the American championship. The rebounds, and in particular the defensive ones, are a KPI that contributes strongly to the final result and the players who are able to ensure a greater number of this variable are the most wanted and desired by the best clubs, this ability could be associated with very high game rhythm levels that contribute to more fast-break ball possessions (Lorenzo et al., 2010).

The difference between the guards, on the other hand, has shown that the players of the European championship scoreless 3Pta than the Asian guards and generate more PF, data shared by previous studies who suggested that European guards are more cautious and tend to pull less from long distance, often because European competitions have fewer possessions (Madarame, 2018a). As for the fouls, Sampaio and Janeira had suggested that the fouls are an effective way

to recover the ball and stop the action, especially when the opposing player has the opportunity to go to the basket easily and is a tactic of the coaches for "break" the rhythm of the game and adjust the tactic without using a time-out (Sampaio & Janeira, 2003). Another important factor observed in the guards is the offensive contribution through assists, to achieve an assist the player should not only be skilled with the passing and management of the ball, but also know how to understand the game, have the ability to predict the movements of companions and opponents and find the best timing to make the pass (Gómez et al., 2008; Lorenzo et al., 2010). The European and American guards are able to make more assists than the African ones, highlighting how the attack in Europe and the USA is better organized. Another interesting aspect of the study regarding the guards was that of the turnovers, in fact the African players have made more TOV than the players of the other continents, connecting, probably, to the organization of the game of the different championships.

The study of the Chinese team then moves to forwards, players who perform more than one task on the field and are very versatile for coaches and their tactical choices during a game (Kucsá & Mačura, 2015).

The African forwards generate more 2Ptm and 2Pta than the European counterpart, this result reflects a typical strategy of the African game, more concentrated in the offensive game within the line of 3pt. In addition, this results about African league study were consistent with previously reported findings that African forwards tend to utilize free throws to scoring due to a different behavior in isolation situations and using the body with more energy (lay-ups and paint penetrations) which could lead to more physical contacts to free throws (Paulauskas et al., 2018).

1.3.3 Performance indicators for the success

The use of GRS allows to have objective variables that describe the competition and thanks to these it is possible to get important information to better understand the game.

An interesting work on GRS that allow to discriminate winning teams from those losers has been done on the Spanish women's championship, where it was observed a total of 178 games in the regular season 2004/2005, with the objective was to identify variables that differentiated the final score and identify those linked to the teams with the most wins (Gómez et al., 2006).

The analysis reveals several scenarios, in particular when the matches were balanced (matches with a final result of less than 12 points), the winning teams obtained a greater number of free throws, 3ptM, assists and defensive rebounds. As seen above, more athletic players with better skills are able to take more rebounds, thus generating more second chances or, in the case of defensive rebounds, avoid that the opponent can try the wrong shot (Paulauskas et al., 2018). It is normal, from better teams, to expect the team's players to be physically and tactically stronger and capable, according to Sampaio and Janeira (2003), high-level performance is closely associated with the pace of play, which implies knowing how to handle more ball possessions, from here you can explain the relevance of assists that generate advantage through a good handling of the ball and teamwork (Sampaio & Janeira, 2003).

As regards the games with a final result greater than 12 points, and therefore unbalance, the results are comparable to other research on men's basketball, where the success is mainly determined by 2ptA and 2ptM, stolen balls and defensive rebounds (Leicht et al., 2017a). In this type of competition with a large difference in points, one of the two teams is able to generate more points through medium and long-distance shots, as well as control the pace through defensive rebounds. The stolen balls would be the reflection of better tactical preparation of the players, index of better players, who are able to change the possession of the ball and thus generate more chances to score. The Spanish research group (Gómez et al., 2007) even analysed

the game location and observed differences between home, away, and aggregate to identify the main variables that discriminate between winning and losing teams, showing results similar for all the matches considered, but when it observes only the games at home the visiting teams have a major disadvantage, in fact the home teams have a much higher winning percentage, 59.6%. The biggest differences between home and away teams are, again, defensive rebounds, steals, assists and two points scored, suggesting that the great psychological pressure that can generate the home audience seems to affect game variables and player behaviour. The stolen balls can be a clear sign of how a player has more courage thanks to the support of the home crowd and create more pressure during the defensive phase. The defensive phase is then reflected on defensive rebounds, where the importance of not giving the opposing team a second chance makes the players more combative and ready during this delicate phase of the game.

Even the points scored within the 3pt line are an important variable for home teams, having more landmarks and experience with home baskets manage to score more points.

In general, the fact of playing outside the house can psychologically affect and generate some physical problems due to travel and sleeping outside the house, influencing the motivational part and the physical performance of the athlete and probably weakening some variables highly related to performance, such as concentration and self-control (Thout et al., 1998).

Analyzing the away games, the study shows that the difference between losers and winners is determined, as well as by defensive rebounds, even free throws, the two points scored and the wrong 3 points. These observed variables reinforce the idea regarding the importance of defensive rebounds in women's basketball for a positive final result and, as for the two-goal shots and the shots from the wrong 3, it is clear that the selection of the shot and the decision is vital when the game is played away. This result can be explained by a greater defensive pressure of the home team that does not allow shooting from a wide distance. Instead, regarding the free throw, the winning teams outside the house show great importance in getting points through

this shot. As we saw earlier, the free throw allows you to score high percentage points at key points in the game, despite there being a great psychological component in it.

Studies concerning the analysis between winners and losers have a great importance to generate a solid foundation theory and practice-wise to help coaches and sports-workers get the best results.

On this idea, we find other more recent studies regarding the European competitions of women's basketball, such as that of the group of researchers from Serbia, leaded by Slobodan Simović who observed 40 games and thirteen variables of standard efficiency recorded at FIBA eurobasket Women 2017 (Simović et al., 2019).

In this paper we explore variables in relative and absolute terms, finding concordance for most variables that discriminate the result.

In both observed models, variables included were related to field goals: in the first, the included variable were field goals made while the second model had the variable of percentage of field goals.

In particular, it has been observed that the winning teams outperformed the losing teams thanks to the offensive aspect, since field-goal shooting is one of the fundamental skills in basketball, this result is well observed in literature, which confirms the importance of the offensive phase in modern women's basketball (Gómez et al., 2007).

In addition to this, other offensive variables have also been found to be significant in the first model of the study, as free throws made and 2 points made, while in the second model the percentage of free throws. Others basketball studies found similar results regarding the correlations between the shooting parameters and final results (Gómez et al., 2007; Milanovic et al., 2016), but just one the significance of 2 points made in a women's basketball study (Gómez et al., 2009).

As for the statistics of the losing teams, personal fouls are higher than the winning teams,

contributing to the idea that the offensive organization of the best teams contributes to increasing the high-risk defensive situations, players trying to take away the chance of shooting opponents have a greater chance of committing foul, as other studies in women's basketball have highlighted (Gómez et al., 2019; Milanovic et al., 2016).

Continuing the discourse on non-invasive variables, in the study of Simović and colleagues, are mentioned efficiency percentage of defense rebounds in relation to field points missed by the opponent, percentage of personal foul efficiency, and turnover percentage of inefficiency.

As it was easy to expect the winning teams recorded more defensive rebounds than the losers as well as more rebound attempts. As previously seen and confirmed by other studies on women's basketball, rebounds are a KPI to discriminate the final result, especially because they allow, in the case of offensive rebounds, to generate second chances and to control the pace of the game with regard to defensive rebounds (Gómez et al., 2007; Leicht et al., 2017a).

A further aspect taken into consideration are offensive turnovers, an important variable already underlined in the literature (Milanovic et al., 2016) that can be well defined as “the result of poor ball passing or receiving, travelling or double dribble and a violation of rules (stepping out of bounds, shot-clock violation, illegal screen, palming, three-second or five-second violation, etc.)” (Simović et al., 2019). We can differentiate turnovers between two sets, one regarding the players skills, for example difficult situation like bad passing or poor dribbling skills or, the other, regarding the game violation rules, like resulting in the loss of a ball possession - the skills set of turnovers, as a result of aggressive defense, affect more the rhythm of the game since the opposite team try to open space to move the ball up the court and obtain a good vantage position in a quickly way. As you can guess, the stronger teams have fewer turnovers that allows them to control the ball possession and have more offensive possibilities.

The search for association between indicators of performance and success during women's basketball competitions also moves into the sphere of Olympic competition (Leicht et al.,

2017a; Milanovic et al., 2016; Leicht et al. 2017b).

The Olympics are a competition that takes place in a limited period and with players who have little time to learn how to build a united group and know how to exploit the partners for a better result. This also applies to the staff, which increasingly often consists of professionals who work in club teams, and in a short time must adopt the best strategies to operate the group and the uniqueness of each player.

The study conducted by Milanović and colleagues had the goal to determine differences in situational efficiency parameters among successful and unsuccessful female basketball team during the Olympic Games in London 2012 (Milanovic et al., 2016). In that case, the variables that mostly differed the Olympic teams, were 2 points-fail, 3 points-fail, defensive and offensive rebounds, and turnovers.

In the London Olympic games, the 2 points-fail appearance as the most important factor to discriminate successful and unsuccessful teams. This appears clear when the successful teams have more good option to score from favourable positions and with a better shot selection in those zones of the court where the percentage of success is higher. Alonge with 2 points-fail, 3 pints-fail represented another significant contributor o discriminating teams, the stronger teams had a lower percentage of 3 points-fail. Probably, the good quality of defence of successful teams, forced the weakness on higher number of unsuccessful shots, both from two and from three points. Regarding the defence, turnovers had a smaller but significant contribution on final score.

The turnovers, as we explained before, have an important role in the balance games and an aggressive defence, with high pressure, generate more inaccurate passages and change of possessions, permitted to other team to have more options and relevant ball possessions.

According to 2 points-fail and 3 points-fail, the results of offensive rebounds in the study shows a negative contribution on the efficiency, this can be explained by the better percentage of

stronger teams in the shooting, even if an aggressive offensive rebounds attitude represent more options to catch and conquest the possession.

Another work observed and examined the relationship between team performance indicators and game outcome during the women's basketball tournament at the Olympic Games, from 2004 until 2016 (Leicht et al., 2017b).

The research founded a high probability to win (91.1%) combining field-goal percentage, defensive rebounds, steals, and turnovers, while a unique combination of field-goal percentage, steals, and turnovers offered the lowest probability of winning (3.3%) and the greatest probability of losing (96.7%).

In that study, the researchers confirmed that field-goal percentage, defensive rebounds, steals, and turnovers are indicators sex-independent and significant to the success at current Olympic level, highlight shooting proficiency and defensive actions as really important for success of men's and women's basketball.

At the same time, the effect of steals was a key indicator founded for the success of a team. This result is supported by previous research (Leicht et al., 2017a), especially in Spanish Women's league (Gómez et al., 2013) and confirm the importance of steals as a vital skill for athletes and relevant to train for the coaches.

In addition, coaches of women's teams are encouraged to develop strategies to improve steals in elite basketball games. These strategies can include full-court and half-court pressure as well as double-teaming players to increase the chances of a successful play (Gómez et al., 2013; Gómez et al., 2006). In addition, the selection of athletes with high fitness characteristics may be important for the stolen generation. Steals have previously been associated with high-velocity agility and anaerobic power in elite youth and female basketball players (Vanmeerhaeghe et al., 2016). Adding players with these qualities to national teams can create a talent pool to improve game steals and ultimate success.

This degree of familiarity, focus, and discipline may be difficult given the limited preparation time and match opportunities for national teams that include athletes competing potentially in every corner of the world.

Engaging players that are familiar with each other and controlled games style (Gómez et al., 2017) or who are more tactically trained (Gómez et al., 2013) can provide more defensive and offensive actions for a positive outcome. This level of focus on familiarization and training can be challenging given the limited preparation time and opportunities for a national team that includes players from different clubs.

Regarding young players, literature allows us to take an overview and evaluate differences in basketball game-related statistics among continental championships for U18 women, and, moreover, to identify game-related statistics that discriminate among the continents (Madarame, 2018b).

In 2018, Madarame, analysed 136 matches in the four (Africa, America, Asia, Europe) U18 women's continental championships of 2016, discovering that U18 women's games are played differently in each continent.

The study found large effect size differences in 10 of 16 game-related statistics, discovering the high contribution of assists and fouls in the Asian championship and the highest number of ball possessions among the four continental championships, indicating that the Asian games are characterized by a relatively fast pace and a great number of personal score points made.

In addition, the U18 women's Asian championships showed the lowest numbers of fouls, free throw attempts, and turnovers respect the other continental championships. These results maybe they are to indicate that women's games in Asia are offense-oriented and/or less physical.

Regarding European championship, Madarame (2018a), displays as players from the old continent are distinguished by point difference and ball possessions which suggest a championship characterized by slower pace respect the Asian and with more closed outcome

games. These European characteristics are previously observed in another studies about junior and senior man competitions (Ibáñez et al., 2018; Madarame, 2018a), It reinforces the idea that the club-based player development system in Europe can contribute to the formation of European-style basketball that does not depend on age or gender.

Three-point goals and free throws played a major role in distinguishing the U18 African Championship from other continental championships. The number of successful 3-point field goals at the U18 African Women's Championship was the lowest among the four continental championships and the number of attempted free throws at the U18 African Women's Championship was the highest among the four continental championships.

For a mayor offensive attitude of American games, the U18 Women's Americas Championship has the most points three-point free throws and assists among the four Intercontinental Championships. However, the U18 Women's Championship of the Americas had the lowest number of two-pointers among the four Intercontinental Championships. When the shooting data is converted into a percentage value the USA U18 Women's Championship ranks first in two-pointers and three-pointers and second in free throws in four Intercontinental Championships. These results suggest that on average American players possess good shooting skills. In addition to good decision-making and passing skills as well as a high assistant count it can also be one of the reasons for the outstanding performance of women's shooters in the US Championship.

1.3.4 How the bench affects the game performance

Club teams are often built to get the best performance at the lowest cost, in Europe, with its format of relegations and promotions, but also in the USA, where the franchises always play the same championship, trying to get the best place in the standings to continue with the playoffs and hope for the championship victory.

As a result, each team will have a mix of veteran players, young, with more or less big ambitions, but especially players who will start on the field and others who will have to work hard to play from the first minute of the game.

In this scenario, there is a study on differences in game-related statistics between basketball starters and nonstarters players when related to game outcome and team quality in women's basketball (Gómez et al., 2009).

The Iberian research group obtained the data from the 2005 regular season official box scores ($n = 216$ games) of the WNBA (Women's National Basketball Association). Women's players were classified as starters ($n = 2,134$) or nonstarters ($n = 1,643$) as they were selected or not for the starting five of the team.

The main characteristics founded were the successful 2-point field-goal, successful free-throws and assists that permit to discriminate starters from nonstarters players. These variables suggest the importance of field-goal selection after good passes and the ability to have a good decision-making process during the match. As we explained before, the importance of 2-point field goal and assist success in the women's basketball team is strongly associated with victory (Gómez et al., 2013) and is the basis of exceptional efficiency that shows the best tactically trained team with a defined role. The fact that starters made more 2-point field goals and assists, indicates better psychological responses such as better role efficacy and willingness to stick together resulting in better performance on the field (Sampaio, 2006), as well as unfavourable psychological conditions, given by negative comments or fierce fans that can affect the performance of less skilled players, who have a few minutes and opportunities during the game, compromising the offensive performance (Gómez et al., 2013).

Even regarding the differences in free throws performance was explained by psychological aspects like concentration, motivation and self-confidence, but also by technical skills and experience.

Regarding defence-related variables, the study showed differences in defensive rebounds and fouls, reflecting a better ability to catch the rebound and take more advantageous positions under the basket and, on the other hand, the lower fouls committed suggest a better defensive skill, communication and aggressive attitude that decreases the opponent offensive players' abilities (Trninić et al., 2002). So, it is not surprising that starters are more confident and aware of the task because their defence preparation is better than non-starters.

The descriptive results reflect that the worst teams lost because the starters performed worse. These results differ from those of the best teams reflecting that the best teams need better starting and non-starting performances to win games while the worst teams need better starting performances to win games. These facts increase the importance of team cohesion between the two groups. According to Bergeles and Hatziharistos (2003) when starters pull each other towards the same competing goal team performance improves and leads to higher results (Bergeles & Hatziharistos, 2003).

1.3.5 Situation variables affect the game performance.

Another important topic in the research of sports performance is to understand the situation variables and how these can affect competition, especially in the gender distinction, a disparity between men and women has been observed, where the latter could be more affected (Gómez et al., 2013).

In particular, the situational variables were game location, quality of opposition, score-line or game period in performance (Sampaio et al., 2010).

In the study of Moreno (2013), they were taken into consideration 364 games played by fourteen participating teams in the 2009/2010 and 2010/2011 regular seasons of the Spanish women's professional league and the purpose of the study was to determine the impact of the starting score line on the outcome of the quarter-final matches considering the quality of the opponent and the playing position (Moreno et al., 2013). The results support the hypothesis that the final

outcome of women's basketball is influenced by situational variables.

The results of the study show us how, regardless of the time of the season (whether regular season or playoff games), the location affects in the first 35 minutes of play, while in the last 5 there is a greater predominance of the score-line.

Thus, the importance of each game's context (i.e. balanced or unbalanced game quarters, starting quarter score) appears to moderate the importance of each situational variable and their contribution to each quarters score variance. First quarter scoring effects were only significant in all games and second quarter in unbalanced games, but not in balanced games quarters. On the other hand, in the second game quarters, the results showed a decrease when the quarter starts, maybe for a higher game intensity.

In contrast, the effects of the quality of the opposition were founded significant in al situations, suggesting a higher predictability in unbalanced game quarters and a less probability to predict the outcome in balanced game quarters.

Another important factor that was founded in the study is the home advantage, especially during the first half of the match, probably for the home support, the familiarity with the court and a more aggressive playing tactics (Pollard & Gomez 2015). Previous studies evidenced the importance of home advantage (Madrigal & James, 1999). Team quality and the home advantage, testimony the importance of self-esteem and self-efficacy in female athletes, because they are more influenced by environmental conditions than by their own mistakes or by the support of rival spectators.

1.3.6 Offensive and scoring strategies in women's basketball

The offensive game, in basketball, lends itself to many combinations and different strategies.

As we have seen, previous studies (Delextrat et al., 2015; Gómez et al., 2013; Zhai et al., 2020)

have shown how the offensive role of each player is dependent on the team's playing style, by the country where the competition is playing, physical characteristics and the situation variables that occur during the game.

Over the years has been observed a great effectiveness of turnover and rebounds, especially offensive, to quickly get to the basket and create second opportunities to increase the score. To better understand the offensive situations of modern women's basketball, we come to the aid of a study of 2017, which analysed the offensive strategies during FIBA EuroBasket, looking for the main differences in the scoring tactics between winning and losing teams (Conte & Lukonaitiene, 2018).

The study examined 16 teams that participated in the final stages of the tournament, divided into clusters by final score (score difference: "close" 1–9 points; "balance" 10–19 points and "unbalance" 20–33 points). The first parameter they took into consideration were the fast break points: it is interesting to note that they did not observe substantial differences between winning and losing teams, as on the contrary is evident from some previous studies (Conte et al., 2017; Evangelos et al., 2005; Ortega et al., 2007). being an offensive situation with a high scoring percentage (i.e., 63–73%), is commonly associated with teams better organized in attack and able to, in a few seconds, create a situation of great advantage (Conte et al., 2017; Garefis et al., 2007).

The explanation could be in the type of competition, where close matches prevent you from having a thorough scouting and play more calmly, moreover, fast break action requires a high level of fitness while in a tournament scenario with a busy schedule players may want to slow down to avoid possible fatigue at the end of the game (Conte et al., 2017; Montgomery et al., 2008).

Another parameter observed was the high number of points in the paint and points from turnover.

Points in the paint have been identified as one of the main indicators to differentiate winning teams from losing teams in an unbalanced game. The importance of the inside game is also well documented in women's basketball (Gómez et al., 2013). Gomez (2013) emphasized that in the women's professional basketball league action is most effective when it is taken in key areas, like in the paint. Therefore, the importance of play in the inside game of elite women's basketball games is also an important prerequisite for offensive rebounds and the second opportunities they generate. In fact, they were observed, during the balanced and unbalanced games, that the winning teams scored a significant higher number point from second changes, reinforcing the importance of the internal game.

The great importance of turnover is given by the possibility of getting to the basket quickly and with the advantage of numerical superiority. It requires excellent athletic skills and technical skills to anticipate the opponent. Previous studies have shown that turnover is a key variable in women's basketball (Leicht et al., 2017b; Teck et al., 2012) and Conte and Lukonaitiene (2018) highlighted the majority of points from the turnover of winning teams, especially in unbalanced games, confirming the idea of the importance of adopting game strategies based on turnover.

The role of the bench, in women's basketball, is determined by the ability to work in a team with the rest of the group and the individual skills of individual players. Analysis of points generated by the bench are in contrast if you observe unbalanced matches or close. It was noted in the study that winning teams have more points off the bench in unbalanced games, this could be an indication that during easier (or more difficult) matches there is more room for players starting from the bench, on the contrary, during games with a closer final outcome, winning teams have fewer points scored from the bench, This could be explained by greater demand from the stronger players in difficult games where every offensive situation is important and the action ends with shots from the players in the starting five (Conte & Lukonaitiene, 2018).

The offensive phase of a team ends, most of the time, with a shot to the basket, one of the most

important technical actions, to try to add up points and get more of the opponent at the end of time and get the win.

Many complex factors affect the shooting results, that's depend by the angle and the distance of shooting, the defensive style of the opponent, the place where the shoot starts in the court and how the attack situation was made (Erčulj & Štrumbelj, 2015). The number of shots from close and medium distance is decreasing due to the increasing variety of offensive tactics and better opportunities to shoot accurately into the basket from long distances (Sampaio & Janeira, 2003).

Starting from 2003 European Championship, there was a clear decline in points scored, from 74 in 2003 to 65 in 2009 (Kreivyte et al., 2013). As we have seen, several factors influence the percentages of shots scored, like the opponents' style of play, the number of very capable players in the team, team tactics in a game, etc., probably caused by better defensive skills of the players, level of training equalized between rivals and some differences in the rules (Csataljay et al., 2009; Gómez et al., 2006).

Over time, there has been a greater organization of the offensive game, with slower rhythms and a search for shots that could ensure more chances of success. The more tactically organized teams have a greater number and accuracy in near and medium range shots, in particular, it was observed that teams with a slower game pace had a better percentage of the shot from close and mid-range distances (Scanlan et al., 2016).

An increase in long-range shooting has been observed since the 2001 European championship, in fact it has been observed that the that the number of long-range shots, during a match, of eight best women's basketball teams in the 1995 championship was 9, while the teams performed 16 long-range shots during 2011 european match (Kreivyte et al., 2013). Despite these observations, shooting strategies also depend on the game situation, Kreivytė & Čižauskas (2010) pointed out that team choices in the final shots depended on the result, opting for closer

shots at a higher percentage when the game was point to point (Kreivyte et al., 2013).

One of the shots with the highest percentage are the free throws, they are influenced by various psychological factors, but also by the result and the moment of the match (Ibáñez et al., 2015). In closely contested games, free-throws have been reported to be vital for the game final outcome (Moreno et al., 2013). In WNBA league, season 2022/23 it has been observed that the mean accuracy of free throws of the basketball players per match was 83,2%. A poor percentage of execution is generally considered around to 65% as the accuracy of top basketball players usually reaches 90% or higher in a game. Even the free throw is changing during the years, in European Champion of 1997, in one championship match, the average of 28 free throws was made, with 22 shoots scored (79% accuracy), while in 2011 European competition just 17 free throws was attempted (Kreivyte et al., 2013).

1.3.7 The shooting options in youth female basketball.

The growing interest in the development of young athletes, the technological advance with consequent lowering of the prices of the instruments of analysis and the raising of the technical level, scientific and skills in youth staff has made it easier to obtain important data to better understand the game outside of professional or senior competitions.

The basketball research has shown that winning teams performed better than losing in shooting field-goals (Sampaio & Janeira, 2003; Trninić et al., 2002), regarding young female athletes there is differences between local to international competition, in the case of Lithuanian players, they performed 5% less two-point field goals and with 17% less accuracy in the European competition respect to Lithuanian league, reflecting the high defence intensity in the international competition (Valinskaitė et al., 2018).

In youth teams participating a national league, it's found high correlation ($r = 0.54$; $p < 0.05$) between scored points and missed points and between scored points and the difference in scored

and missed points ($r = 0.91$; $p < 0.05$) allow and emphasize that successful team actions in defence create positive preconditions for counterattacks and scoring more points (Šeparović et al., 2008; Valinskaitė et al., 2018).

Another interesting component of offensive strategies in youth basketball is the free-throws with a difference between the local and international competitions. Seems really important during local competition, as a great part of points scored during the match and with a major impact on the final outcome (Valinskaitė et al., 2018), the smaller number of free throws in an international match can suggest a better defence system by opponents and a superior ability to avoid fouls in critical situation.

Regarding offensive capabilities based on roles, the work on youth basketball of the Lithuanian research team takes ultimately with the effectiveness of scored points by players of different positions, clustered in “Guards”, “Forwards” and “Centres”.

The primary role of the guards is to manage the game flow in offensive game phase, with highest number of long field goal and use assist to help the mates to score in a better position. They use a little bit more three-point field goal in local games, but the greatest difference is in two-point, with 3-4 times more percent of accuracy in local competition, while a stable free throws shoots in both competitions, suggest the difficulty of international competition to try the long shooting (Valinskaitė et al., 2018).

Regards forwards, they are generally considered a type of player with many different options that are interposed between guards and centres. The additional characteristics of their performance are: high attempted throws from both the half-distance and distance (although the guards have more three-point goals attempted) and a significant contribution to the flow of performance by a great number of passes (Trninić et al., 2002). In the international competition, the performance of Lithuanian youth team forwards was minor, with a reduced efficacy of shooting in, respective, less 14% in two-point field goals and less 15% in three-point field goals,

moreover with the free throw efficacy inferior by 24%.

The last group was the centres, they showed an high ability on shooting under the basket, a steady accuracy percentage in two-point field goals in any competition, while a surprising higher accuracy in three-point shoot during the international competition, showing that the opponent's defence during international competitions is concentrated in the areas near and below the basket, leaving more space for the perimeter shots (Valinskaitė et al., 2018).

1.3.8 Altering a rule has the potential to transform the entire game.

The playing style, strategies, and individual characteristics change as the age and level of competition progresses, through training and youth competitions, the player develops their own characteristics over time and improves his understanding of the game. An important adaptation that must be faced during its maturation is the modification of rules, the size of playgrounds and the equipment used. In fact, the rules, spaces and equipment change the nature of the sport. Ibáñez, Feu and Dorado (2003) findings confirm some patterns, like higher values for effective field goals and turnovers per ball possessions for U20 category compared to U16, indicating that with age, teams play with less ball possession and offensive efficiency increases (Ibáñez et al., 2013). According to the authors, development in elite basketball is not evenly distributed, which is the reason for the age and inexperience differences among younger players.

Sampaio et al. (Sampaio et al., 2004) confirmed the age advantage as juniors are more revenue-oriented and less focused than seniors showing poorer selection of shooting opportunities and less attacking efficiency. Lorenzo, Gómez, Ortega, Ibáñez and Sampaio (Lorenzo et al., 2010) adds that these results may indicate that U16 players make errors due to the difficulty of keeping possession of the ball, the increase in the quick break occurs and the pace of play.

The study by Veleirinho and Tavares (2013) also points out that the winning teams, especially

in balanced matches, show better values in assists and turnovers. However, it does not seem fair to infer that a reduction in the pace of play, probably reducing possessions and the risk of errors, guarantees better rates to the U16 category. Paradoxically, as reported by Ortega and colleagues at this age level, note that the winning teams frequently play fast-break, using shorter times in attack (Ortega et al., 2007).

There are studies (Gómez et al., 2006; Gómez et al., 2009) that emphasize the significance of 2PM in female basketball as a factor that correlates with victories and the basis for offensive efficacy, which reflects tactically disciplined teams with defined responsibilities (Gómez et al., 2009; Gómez et al., 2013). Although there were various viewpoints, this factor did not reveal significant differences between groups, suggesting that other factors are responsible for this advantage in EFG to the U20. The reason appears to be due to the inversely proportional ratio between the categories, where U20 produced more baskets in fewer attempts than U16. On the other hand, the 3PM and 2PA significant differences that occur by the U16 and U20 categories ceased to exist from 2010 to 2011, a possible effect of 3-point line change, make the play more uniform across the ages of this aspect (Veleirinho & Tavares, 2013).

The development of the game and the rules generate a change of strategies and tactics during the matches, in the training sessions and included in the selection of players by the staff. The research and analysis of matches through their changes over time is crucial to better understand each feature of the game and give coaches the best tools to face competitions.

1.4 Understand the workload demands during competition.

In competitive sport, there is a need to use different training methodologies to improve the physical and technical skills of players. Basketball is an intermittent sport, with moments of low intensity alternating with great expressions of strength, speed and intensity of specific movements of the discipline (Scanlan et al., 2012). To meet the growing needs of competition, training methods have been developed designed to increase metabolic capacity, speed and agility, strength, and muscle power, as well as training skills. In addition to these means of training, the coaching staff generally implements the training session with exercises of conditioning metabolism through the game, using specific means such as small-sided games and exercises very similar to the competition, since this simulates the conditions that are found during the games of the season, both physically, but also mentally, technically and cognitively (Clemente, 2016; Hill-Haas et al., 2011).

To organize and control the different training sessions it was essential to monitor the physical state of the athlete and have a comprehensive and comprehensive view of the training process during the season. There have been changes and evolutions, both in the world of research and in that of practice, on how to monitor the physical state and the difficulty of training. Initially, information on the status of athletes was obtained from individual tests on the physical abilities of athletes, which could be related to metabolism, fatigue or potency, or biological components as markers in blood or other tissues (Foster et al., 2017). These methods involved important limitations of organization, costs, specialized personnel and will of the athlete, as well as, sometimes, lack of evidence and relationship with performance, which resulted in a lack of use and dissemination at all levels of sports (Fox et al., 2018).

In recent times, there has been an interest and development on the measurements that the athlete can self-generate. These perceptions of the athlete have a basis of studies previously carried

out, also on aspects related to training such as recovery, fatigue, and muscle soreness. They are extremely interesting because they are based on the athlete, have a sensitivity to variations during training and related to the physical, psychological, and physiological load, as well as extremely convenient to use and low cost. At the same time, thanks to technological development, wearable sensors are being developed, capable of measuring objective variables such as distance travelled, accelerations, jumps and many other variables related to sports performance (Saw et al., 2016; Thorpe et al., 2017; Watson et al., 2017)

As we anticipated, the management of workouts through monitoring is vital to improving the performance of basketball players (Taylor et al., 2017).

The subjective workload, measured through self-reported questionnaires by players, is called internal load, while the objective data acquired through devices is classified as external load.

the combination of these two methods of management and monitoring of training loads is necessary to perfectly understand the course of training and the stimulus that is proposed to athletes (Drew & Finch, 2016; Jones et al., 2017).

1.4.1 External workload in basketball.

Before the technological development and devices able to measure objective data directly on the athlete, the external load and its variables were quantified through the video analysis of the movement of individual players thanks to temporal motion analysis (TMA) (Abdelkrim et al., 2010).

This method allows to obtain variables of easy acquisition like the speed and the distance covered, in a reliable and stable way (Fox et al., 2019; McInnes et al., 1995). However, it requires a high level of competence in the management of TMA software to obtain precise data and it is not always possible to capture intermittent movements, such as accelerations, changes of direction and jumps, which are on a three-dimensional basis, or very intense but extremely

close movements, such as the contacts that are generated under the basket between players, extremely frequent in basketball, especially for some specific roles (Fox et al., 2019; Scanlan et al., 2012). Moreover, the logistic difficulties that are introduced for the conformity, dimension and different heights between basketball courts renders the methodical TMA not much used.

All these limitations associated with TMA have created a growing demand in the sports world to be solved with another type of technology. In more recent years, microsensors have developed that are increasingly used in basketball (Ortega et al., 2019; Schelling & Torres, 2016). these microsensors are geolocation systems with global positioning (GPS), with local positioning (LPS) or ultrabroadband (UBW), but also accelerometers, gyroscopes, magnetometers or a combination of these inertial sensors. The choice of the instrument comes from several factors, even logistical, for example a GPS sensor will be of little use in basketball as it is a sport that is commonly practiced indoors and therefore there would be interference and signal problems. A similar approach to GPS is the LPS or UWB system, which allows you to keep the signal within the boundaries of the game structure (Fox et al., 2019). In indoor spaces, they use receptors and antennas positioned on the sides and around the field, which will receive information from microsensors worn by athletes who will provide data on kinematic variables. As for the validity of the monitoring system, two studies confirmed the validity of measuring the external load of players, through linear speed and distance during workouts and matches, even if they had few participants (Luteberget et al., 2018; Serpiello et al., 2018). Apart from this, the LPS and UWB systems have shown poor validity in measuring speed in COD and for measuring acceleration differences, both positive and negative (Serpiello et al., 2018). This difficulty in collecting reliable data is problematic in a sport such as basketball, where rapid movements and changes of direction are very frequent and an essential part of the game (Taylor et al., 2017). Another downside of these technologies is their cost, although thanks to progress

and scale industry the price is falling, these systems often have prohibitive prices for most teams and only those with higher budgets can think of buying them. Apart from the living cost of the system, logistical problems also remain, not always the spaces for installation are suitable and it is not very practical to relocate the systems in non-proprietary arenas, for these reasons the LPS and UWB system has not yet had a large spread, as opposed to inertial sensors integrated in microsenors, which do not need external structures to obtain data and are priced tens of times lower. The limitations of the latter are the impossibility of having conventional data such as the speed and linear distance travelled, moreover the data provided are in the form of arbitrary units (AU) which represent the complex movements of the players and summarize them in one or a few values easily interpreted by the staff, but still through calculations and formulas that are often proprietary of the company difficult to modify, this arbitrary units is also represented as PlayerLoad (PL).

Using inertial system, permit to quantify the motion and this is usually calculated using an accelerometer to combine the instantaneous rate of change of acceleration in three planes of body motion (eg anteroposterior-postomedial-lateral and vertical) according to the following formula (Montgomery et al., 2010):

$$\text{PlayerLoad} = \sqrt{\frac{(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{100}}$$

Where: A_y , x_2 and A_z represent the instantaneous rate of change in acceleration in the three planes of body movement.

1.4.2 Internal workload in basketball.

In contrast to the external load, the monitoring of the internal load comes from the sensations and perceptions of the athlete, providing information on the training, the match or the physiological functions to the coaching staff (Akubat et al., 2014). There are several ways to monitor the internal workload in basketball, each with its own strengths and weaknesses. One of the main methods, especially thanks to the ease of use and its low price is that of heart rate (HR), commonly used to have an objective and physiological measurement of the athlete during the activity, through the average HR, the peak reached in HR (HRmax) and the time spent in HR intensity zones (HR Zones) calculated on a percentage of HRmax (Narazaki et al., 2009). The downside of HR is that you can underestimate the intensity of the activity for a delay in the transmission of the signal and the rapid changes of intensity cannot be recorded or with a significant latency (Scanlan et al., 2014). To solve these problems, we studied the SHRZ model (Summated-Heart-Rate-Zones), which allows to objectively measure the internal workload of basketball players, through specific software or custom spreadsheets (Manzi et al., 2010; Scanlan et al., 2019).

In addition to objective data, such as those taken through HR sensors, you can use tools that give perceptual and subjective information directly from the sensations of the athlete, to determine the internal workloads in basketball.

This method uses a perceived effort assessment scale (RPE) to indicate the intensity of the perceived effort during the training session, physical activity or match (Fox et al., 2017).

The value of the RPE is measured in arbitrary units (AU) and provides an indication of the difficulty of the session, during the years of use was perceived the need to have a value that also takes into account the volume of training and was obtained the RPE session (sRPE) (Foster et al., 2001).

The sRPE is a means that helps to better understand the volume of internal workload perceived during physical activity and its formula is as follows:

$$sRPE = RPE * duration$$

Where RPE = evaluation of the perceived effort reported by each player and duration = training session or duration of the game in minutes.

The sRPE shows several advantages that have allowed a wide spread in a short time at all levels of sports, among them we find: an extremely low cost because you need only a spreadsheet and a register to mark the perceptions of athletes, the ease of data collection as it can also be taken remotely through a telephone message or an online questionnaire to be filled in and finally a great simplicity of calculation and the necessary formulas (Coyne et al., 2018; Saw et al., 2016). Despite the practical advantages, however, the use of sRPE has several proven limitations. For example, sRPE is influenced by psychological and mental factors such as the stress that is generated during difficult situations, the excitement or unhappiness of a defeat and physical fatigue (Smith et al., 2016), It follows that keeping under control and also monitor the emotional states of the athlete could help to distinguish increases of sRPE due to mental factors and not physical or physiological.

This sensitivity of sRPE may make it difficult for staff to make decisions regarding changes in intensity, volume and density of workouts, for this a combination of objective and subjective methods is the best option to faithfully control the training process (Fox et al., 2020).

1.4.3 Total Quality Recovery Scale in Basketball: Optimizing Athlete

Performance and Well-being.

Sports, particularly basketball, demand peak physical and mental performance from athletes (Taylor et al., 2017). The intensity of the game, frequent travel, and a rigorous training schedule can take a toll on players' bodies and minds. To maintain high performance levels and prevent injuries, an effective recovery strategy is essential. One approach gaining prominence in the world of sports is the Total Quality Recovery Scale (TQR) (Kentta & Hassmen, 1998). This scale provides a systematic framework for assessing and improving recovery processes, contributing to better athlete well-being and performance. In this article, we will delve into the concept of TQR, its significance in basketball, and practical applications for athletes, coaches, and sports organizations.

TQR is a holistic approach to athlete recovery that encompasses various aspects, including physical, mental, and emotional well-being. It emphasizes the importance of optimizing recovery to ensure that athletes are consistently prepared for peak performance. TQR is not a one-size-fits-all solution; instead, it involves tailoring recovery strategies to individual athletes' needs and the specific demands of their sport.

The TQR is a tool designed to assess the effectiveness of recovery strategies and help athletes and coaches make informed decisions about their training and recovery routines.

TQR is a comprehensive approach that considers various essential dimensions to enhance an athlete's overall recovery and well-being.

One of these dimensions is physical recovery, which focuses on the athlete's physiological aspects. It encompasses factors like sleep quality, nutrition, hydration, and injury management (Kentta & Hassmen, 1998). Effective physical recovery is pivotal for maintaining peak physical condition. Equally significant is mental recovery in the world of sports. The intense pressure

athletes face can significantly impact their performance. Mental recovery strategies encompass diverse techniques such as relaxation methods, mindfulness practices, and anxiety management, all aimed at sharpening focus and bolstering mental resilience (Balk & Englert, 2020). Moreover, emotional recovery acknowledges the profound influence of emotions on an athlete's performance. It involves managing and nurturing the emotional aspects associated with sports. This encompasses strategies for coping with losses, boosting self-confidence, and cultivating a constructive and positive mindset.

Finally, environmental recovery considers the physical and social environment in which athletes practice and compete. This dimension acknowledges that factors like training facilities, travel conditions, and climate can affect the recovery process and, consequently, an athlete's readiness for peak performance.

The TQR assesses each of these domains, helping athletes and their support teams identify areas that require improvement. It also serves as a valuable tool for monitoring progress over time.

Regarding basketball, it's a fast-paced, physically demanding sport that places unique stresses on athletes' bodies. Players are required to sprint, jump, change direction, and endure constant physical contact (Triguero et al., 2021). The nature of the game, combined with its busy schedule, makes recovery a critical factor for basketball players.

A recent study (Sansone et al., 2023) examined the impact of pre-training well-being and recovery, as reported by athletes, on various aspects of youth basketball training. Specifically, it aimed to understand how these factors influenced subsequent external load intensity, perceived exertion scores, and the resulting efficiency index.

In this particular study, the researchers closely observed and monitored the external load (EL) intensity (expressed as $EL \cdot \text{min}^{-1}$), the ratings of perceived exertion (RPE), and the efficiency index ($EL \cdot \text{min}^{-1} : \text{RPE}$) for a group of 15 youth basketball players. These players had an average age of 15.2 years, with a minimal age variance of 0.3 years. The monitoring took place during

their team-based training sessions. Before the initiation of each training session, the participating players were asked to provide self-reported assessments in several key areas. These assessments covered their perceived levels of recovery, which were gauged using a modified 10-point scale referred to as the TQR scale. Additionally, the players reported their perceptions of fatigue, sleep quality, muscle soreness, mood, and stress.

To analyse the data collected during the study, the researchers employed linear mixed models to explore the relationships between pre-training well-being, recovery, and the subsequent variables of interest, specifically external load intensity, perceived exertion scores, and the efficiency index.

The study's results granted significant findings regarding the relationship between athlete-reported pre-training well-being and recovery and various performance metrics in youth basketball players. Notably, the study observed that when players reported better pre-training recovery, there was a corresponding increase in external load intensity ($EL \cdot \text{min}^{-1}$), a critical factor in athletic performance ($P=0.001$). However, higher ratings of perceived exertion (RPE) scores and lower efficiency indexes were associated with players who reported better pre-training conditions.

Specifically, RPE scores tended to be higher when players reported better TQR scores, lower fatigue levels, reduced muscle soreness, and lower stress scores (all $P<0.05$). Conversely, training efficiency, as reflected in the efficiency index, was lower when players reported higher TQR scores and improved sleep quality (all $P<0.05$). This study's findings shed light on the substantial impact of athlete-reported pre-training well-being and recovery on subsequent external load intensity, RPE scores, and the efficiency index in youth basketball players. The results underscore the importance of monitoring recovery and well-being indicators, as they have a discernible influence on the loads experienced during subsequent training sessions. This information can be valuable for coaches and sports professionals seeking to optimize training

regimens and improve the overall performance and well-being of youth basketball players (Sansone et al., 2023).

Regarding the practical Applications of TQR in Basketball, there are several points that can help athletes, coaching staffs, and sports-workers to manage the fatigue and improve the performance in the basketball court.

The first important point regarding TQR scale is generate an individualized recovery plans for the players and staff: With the TQR, athletes and coaches have the means to craft recovery plans tailored to each athlete's unique needs. For example, an athlete facing challenges in mental recovery can incorporate mindfulness techniques into their daily routine, while another athlete focusing on physical recovery can make precise adjustments to their nutrition and sleep patterns (Kentta & Hassmen, 1998; Smith et al., 2016).

Another part of using TQR during the athletic and performance development of a player is the data-driven decision-making, in fact the regular assessment of recovery using the TQR empowers coaches and sports scientists to make well-informed decisions supported by data. This encompasses decisions related to managing training loads, determining optimal rest periods, and fine-tuning training schedules. Ultimately, this data-driven approach minimizes the risk of overtraining and injuries while optimizing performance outcomes (Kentta & Hassmen, 1998; Sansone et al., 2023).

Improved recovery, facilitated by the TQR, translates into an overall enhancement of an athlete's performance. Athletes who consistently utilize the TQR to refine their recovery routines are likely to experience improvements not only in their physical capabilities but also in their mental resilience and emotional well-being, all of which may contribute to superior performance.

Teamwork is vital to achieving the best results in basketball, beyond individual benefits, the TQR can be harnessed as a tool for fostering team cohesion and bolstering communication

within the team. Athletes and support staff can engage in constructive discussions centered on their recovery assessments, collectively cultivating a supportive team environment that facilitates more effective recovery for all team members.

A last important point is regarding the long-term planning, in fact, in the realm of sports organizations, the TQR can serve as a foundation for long-term strategic planning. By identifying areas that require improvement and meticulously tracking progress across multiple seasons, teams can construct and implement sustainable recovery strategies. These strategies not only enhance short-term success but also ensure the long-term well-being and career longevity of their athletes (Sansone et al., 2023).

In the highly competitive world of basketball, optimizing athlete recovery is essential for sustaining high performance levels, preventing injuries, and ensuring overall well-being. The TQR offers a comprehensive framework for assessing and improving recovery processes in basketball and other sports. By addressing physical, mental, emotional, social, and environmental aspects of recovery, the TQR helps athletes, coaches, and sports organizations make informed decisions that lead to better performance and healthier athletes. As basketball continues to evolve, embracing TQR as a valuable tool for recovery optimization can make a significant difference in the success and longevity of athletes' careers.

1.5 Menstrual cycle in basketball players.

The menstrual cycle (MC) stands as a complex, dynamic phenomenon marked by fluctuating concentrations of sex hormones, a hallmark of female physiology. Recognizing the profound significance of this cycle becomes imperative when striving to optimize the performance and safeguard the well-being of female athletes throughout the rigors of a competitive team sports season.

One conspicuous challenge confronting in sports science field and performance control is the predominant focus on research involving male subjects (Costello et al., 2014). Regrettably, these research findings are often uncritically extended to the realm of female sports, a practice that may lack appropriateness and relevance (Emmonds et al., 2019). To construct a resilient and insightful knowledge base that caters specifically to the unique physiology of female athletes within the domain of sports science, it is essential to start an important line of study on how the various stages of the menstrual cycle affect physical performance (Costello et al., 2014).

The establishment of a comprehensive female-centric evidence base within the realm of sports science is a matter of paramount importance. It entails a critical endeavour: the investigation into the influence of various phases of the menstrual cycle on the physical performance of female athletes. The development and augmentation of this corpus of information, often referred to as the evidence base, hold the potential to usher in a new era of understanding regarding the intricate ways in which the MC can impact athletes.

This pursuit stands as a cornerstone in our quest to refine our comprehension of the female athlete's physiology and the nuanced interactions between the MC and athletic performance. It serves as a catalyst for not only enhancing our knowledge but also translating that knowledge into practical applications. One of the foremost benefits that can be reaped from this endeavour is an improved ability to tailor and fine-tune various aspects of an athlete's regimen, including training methodologies, recovery protocols, and monitoring strategies.

By delving into the intricate dance between the menstrual cycle and athletic performance, we acquire the potential to unlock a treasure trove of insights. These insights, in turn, empower coaches, trainers, and sports scientists to design more effective, individualized approaches that take into meticulous consideration the athlete's MC phase. In essence, this initiative represents a giant leap forward in optimizing female athletes' performance and overall well-being,

fostering a holistic approach that acknowledges the uniqueness of their physiology and ensures that they achieve their highest potential in the realm of sports.

1.5.1 Menstrual Cycle Physiology.

The MC consists of a series of events that prepare the uterus and the woman's organism to undertake a potential pregnancy. A MC that occurs, generally, of regular shape, with a duration between 21 and 35 days, this period of time is defined as eumenorrheic. The eumenorrheic MC is divided into two distinct major stages, follicular and luteal, that occur at the onset of menstruation, follicular maturation, ovulation, and the formation of the corpus luteum (Reed & Carr, 2015).

Nevertheless, the classification of MC using only these two phases does not adequately distinguish the multiple hormonal environments that occur within these two phases. MC is therefore usually defined in studies using substages such as early follicle, late luteal follicle, ovarian, early luteal, mid-luteal and late luteal (Elliott-Sale & Pitchers, 2019). The sub-phases of eumenorrheic menstrual cycle are well displayed in Figure 1, represented by hormonal fluctuation of estrogen, progesterone, follicle stimulating hormone (FSH) and luteinising hormone (LH) (Reed & Carr, 2015).

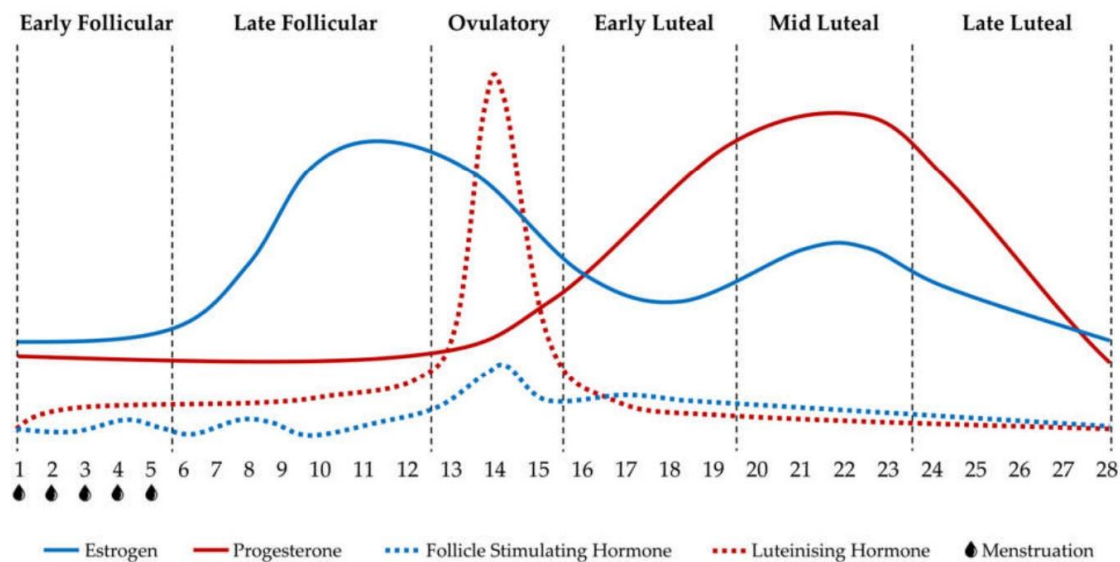


Figure 1. Hormonal events and phases in a eumenorrheic 28-day menstrual cycle

The early follicular phase begins with menstruation and usually takes 4 to 6 days to complete. During this period the concentration of female hormones is relatively low and stable. The follicular phase continues until ovulation. Estrogen increases during the follicular phase when an egg matures inside each follicle. When estrogen reaches a critical point the secretion of gonadotropin-releasing hormone increases leading to a rapid increase in LH. Post-follicular LH stimulation triggers the onset of ovulation in which a ruptured follicle releases a mature egg into the ovary. The early luteal phase begins after ovulation; during this phase the ruptured follicle becomes the corpus luteum and releases progesterone and a small amount of estrogen. The mid-luteal phase has a progesterone peak and another small estrogen peak that prepares the endometrium for implantation of a fertilized egg. If the fertilized egg is implanted then the luteal phase ends with pregnancy. If the egg is not fertilized the corpus luteum sheds ready to start the cycle again and progesterone and estrogen decrease in the late luteal phase when the endometrium finally sheds and prepares to resume menstruation (Patricio & Sergio, 2019; Reed & Carr, 2015; Sohda et al., 2017).

The approximate timing of each MC phase is shown in Figure 1 but the timing of ovulation and

the different MC phases vary widely (Soumpasis et al., 2020). To accurately identify the MC phase, measurements such as urinary LH tests and serum progesterone and estrogen measurements are used due to this variability (De Jonge et al., 2019; Elliott-Sale et al., 2020). The menarche, the starts of MC, generally begins when the subject has 13 years of age (Thomas et al., 2001) and still continue regularly (in a window cycle of 21-35 days) until around 45 years old, when the perimenopause starts (Trévoux et al., 1986), interrupted by pregnancy, any hormonal contraceptive (HC) practice or in case of physiological dysfunction. Most elite female athletes have normal periods (Dadgostar et al., 2009; Verrilli et al., 2018) and around half of them have a HC practice during the competitive period (Larsen et al., 2020; Martin et al., 2017). It is suggested that a significant number of female athletes may experience cyclic hormonal fluctuations based on this.

1.5.2 Proposed Mechanisms behind Menstrual Cycle Based Changes in Performance.

It is proposed that changes in physical performance during the menstrual cycle are caused by different mechanisms such as metabolic changes in the substrate for muscle activation thermoregulation and body composition. Female hormone concentrations can cause changes in force production that can affect muscle tone and strength. Estrogen has a neuroexcitatory effect (Smith et al., 2002) and progesterone suppresses cortical excitability (Smith et al., 2002). Estrogen and progesterone have positive and negative relationships with force production due to their neural and inhibitory actions respectively (Gordon et al., 2013; Pallavi et al., 2017; Phillips et al., 1996; Smith et al., 2002). Presumably low progesterone during the follicular phase will produce greater intensity and strength results especially when postfollicular estrogen

is high and less intense results when luteal phase progesterone is high. The MC stage can also have a significant impact on the rapid production of power. Muscle activation especially the initial firing rate of motor units is a key factor in determining the rapid force generation required to execute explosive movements (Del Vecchio et al., 2019). In two studies of women in the general population early motor unit activation rates in the vastus medialis and medial oblique muscles were significantly higher in the late luteal phase than in the early follicular phase (Tenan et al., 2018; Tenan et al., 2016).

Another possible modulating factor in muscle strength is MC-based changes in available testosterone which was investigated in a study and found no difference in potency or bioavailable testosterone between the prefollicular and mid-luteal phases (Elliott et al., 2003). Testosterone acutely increases physical performance by improving neural function electrophysiological and muscle contractile properties and motor system function (Crewther et al., 2011). Other studies measuring baseline salivary and plasma testosterone levels at different levels of MC phases (Cook et al., 2018; Dougherty et al., 1997) found peak testosterone levels at ovulation and post-exercise salivary and free testosterone levels increased during ovulation (Cook et al., 2018) and during the mid luteal period (Lane et al., 2015). It is not known whether bioavailable testosterone increases during the ovulatory phase compared to other MC phases, when salivary and plasma testosterone concentrations have been displayed to increase (Cook et al., 2018; Dougherty et al., 1997). In the field of research related to performance and hormonal flows, this mechanism is still being studied as it is not clear how it can cause force fluctuations on the MC.

Muscle and tendon stiffness have been examined in several studies to determine whether MC status is a risk factor for soft tissue injuries; several studies have concluded that tendon capacity is influenced by MC phase (Sung & Kim, 2018; Yim et al., 2018). It has been considered a relationship between stiffness of the muscles of the lower limbs and tendons and performance

in tests requiring reactive jumps or jumps (Abdelsattar et al., 2018; Souhaïel & Denis, 2001), such as short sprints or multiple jump tests, as greater rigidity ensures better storage and utilization of elastic energy (Abdelsattar et al., 2018); MC phase may also alter performance through changes in tissue stiffness. It has been suggested that increasing the concentration of estrogen in some phases of the MC can reduce the rigidity by decreasing the synthesis of collagen and therefore the density of collagen in the muscle and connective tissues (Yim et al., 2018). However, the results of studies studying tissue stiffness above the MC conflict. In sedentary females, the stiffness of Achilles tendon, patellar tendon and the the medial gastrocnemius muscle were unchanged in the follicular, ovulatory and luteal phases (Taş et al., 2020). In female athletes, the effort of the Achilles tendon did not differ between the early follicular and ovulatory stages (Bryant et al., 2008). It has been shown that any increase in estrogen during MC is not large enough to cause a significant change in collagen synthesis and stiffness (Bryant et al., 2008; Miller et al., 2007). The effect of tendon and muscle stiffness may vary or not across the MC and have a significant performance impact.

Changes in thermoregulatory set point associated with the rise in progesterone during the luteal phase can have a negative or positive effect on performance depending on the duration of activity. Increased body temperature improves muscle contraction and energy production improving performance in short-duration activities that require speed and power (Girard et al., 2014). It has been hypothesized that the increase in basal body temperature in the luteal phase could improve short-term performance; however, it has been found that an adequate warming protocol before activity, in active form, did not show any phase differences in basal body temperature and will not affect performance (Somboonwong et al., 2015). In endurance and long-term activities, it has been observed that the increase in basal body temperature may impose a greater thermoregulatory and cardiovascular effort and, consequently, potentially limit the performance of resistance, during the luteal phase (Janse, 2003; Marshall, 1963). In

the luteal phase the internal body temperature before and after exercise is generally more elevated respect to other phases, nevertheless, the physiological cooling mechanisms indicated by the sweat rate and skin temperature do not have any difference during the MC (Giersch et al., 2020). Mechanisms that alter substrate availability and metabolism during different stages of MC and affect tolerance performance are also proposed. Estrogen increases the availability of free fatty acids for fuel during exercise and promotes lipid oxidation in skeletal muscle while progesterone inhibits the action of estrogen by limiting fat oxidation (Julian et al., 2017). In a small sample of non-professional athletes, when the proposed exercise was high intensity (90% of lactate threshold), during the middle-luteal phase late oxidation of carbohydrates was lower and fat oxidation was greater than early follicular phase. Estrogen concentrations have been attributed to this change in metabolism because estrogen levels are usually lowest in the early follicular phase (Zderic et al., 2001). Carbohydrate and lipid oxidation remained similar between the mid-luteal and late follicular periods during maximal exercise (Hackney et al., 1994; Vaiksaar et al., 2011). Another study highlighted that free fatty acid availability and maximal systemic lipid oxidation did not change during the three stages of MC despite significant changes in estrogen and progesterone (Frandsen et al., 2020). Pre-exercise carbohydrate consumption was found to eliminate MC phase differences in the relative oxidation of carbohydrates and lipids during prolonged exercise (Campbell et al., 2001; Zderic et al., 2001).

The results of these studies do not provide a comprehensive indication of how substrate metabolism during exercise can affect endurance and long-term performance, however this suggests that metabolism may be affected by the MC phase during high intensity exercise.

A possible mechanism underlying the change in effect could also be represented by transient fluctuations in body composition by MC, a clear example is that when the weight increased there is an association with a reduced aerobic endurance performance (Maciejczyk et al., 2014;

Maciejczyk et al., 2014a). Decreased anaerobic performance is also related to increased body weight and not due to lean body mass (Maciejczyk et al., 2015). As with other proposed mechanisms the effect of MC phase on body composition is unclear. Several studies that measured body composition in female athletes at different stages of the MC determined that there were no noticeable fluctuations in body mass (Julian et al., 2017; Tsampoukos et al., 2010), the sum of skinfolds (Julian et al., 2017; Tsampoukos et al., 2010), fat mass (Rael et al., 2021) and total body water (Rael et al., 2021). However other studies show that body composition is affected. Athletes body weight and total body water increase from the follicular phase to the luteal phase (Stachoń, 2016) and, following, In healthy, non-athletic females, body mass (McKee & Cameron, 1997) and total body water (Fruzzetti et al., 2007) increased from the follicular to the luteal phase in a similar manner. Luteal phase weight gain may be due to decreased insulin and increased progesterone leading to increased appetite and food consumption (Akturk et al., 2013; Dye & Blundell, 1997) or due to increased aldosterone during the luteal phase leading to fluid retention (Szmuilowicz et al., 2006) and may affect performance athletes.

1.5.3 Menstrual Cycle Phase Monitoring in Elite Sport and Basketball.

The use of routine MC phase monitoring is becoming more widespread in elite sport. Elite sports organizations including individual and team sports, at recreative or professional level, in many parts of the world have recently started using commercial smartphone applications to track athletes MC (Dhadda et al., 2021; Trépanier et al., 2023). Players use the app to track their menstrual cycles and various PMS symptoms. Coaches and support staff can access data entered into the app to determine if there has been a change in an athlete's performance or preparation

during various stages of MC. If there are periodic changes in sleep recovery the guidance provided by the app will create a customized performance strategy to address those changes such as changes in the athletes sleep habits training diet or lifestyle factors developed.

In addition to the applications for the various devices, for research purposes, data is often collected through questionnaires and evaluation tables, in particular, it has been observed that a numerical scale to collect data during the cycle and classify menstrual pain is more profitable than a VAS (Larroy, 2002) thanks to this information, players and support staff has the possibility to identify and modify training-based interventions in cases where individuals deviated from their usual menstrual cycles.

Historically, training programs have been designed and proposed with reference to men without respecting the individual and specificity differences that exist between in physiological characteristics in men and women (Arenas et al., 2023).

The use of menstrual cycle monitoring made it possible to further adapt the training to basketball players during competitive seasons (Armour et al., 2020; Ergin et al., 2020). It turned out that, for players, the menstrual cycle and its fluctuations may have some influence on performance, in previous studies, most of the players reported that they felt their performance was compromised at certain stages of the MC (Findlay et al., 2020; Solli et al., 2020). Generally, a worse performance is perceived during the early follicular and late luteal phases, with a perception of reduced ability to express strength, speed and power (Jacobson & Lentz, 1998).

The observation and study of these variables is presented in the work of Dhadda and colleagues (Dhadda et al., 2021), where they took a champion of 80 women basketball players belonging to different colleges with basketball teams, aged between 18 and 25 years. All players were rated the Menstrual distress was assessed by using the Menstrual Distress Questionnaire (MDQ) developed by Rudolf. H. Moos (1969) as well as the phase of the cycle and some tests to assess performance through the Johnson basketball skill test, which consists of three different tests:

Field Goal Speed Test, Basketball Throw for Accuracy and Dribble Test.

The results showed no significant differences in performance between, during and after menstruation, but the players expressed a higher level of stress during the menstrual phase compared to post-menstruation phase. This could be due to menstrual complications and psychological imbalances of the players, although the performance of basketball players during the various test batteries did not show any association with menstrual discomfort and stress during both menstruation and post menstruation (Dhadda et al., 2021).

Basketball is defined as a sport with intermittent phases of explosive actions alternating with moments of low intensity (Moos et al., 1969). A great ability to perform acyclic actions by players and a fast execution speed is required. These actions include COD, jumps, accelerations and decelerations, lateral movements, physical contacts and specific sports skills.

In a previous study it was shown that during the late follicular phase fatigue was reduced, as well as less fatigue and a higher power peak were found together in the final intervals of a repeated cyclic sprint exercise (Graja et al., 2022). In addition, Cook et al. (Cook et al., 2018) also found that during ovulation the power peak had increased and that some psychological and motivational aspects could positively affect training and performance during that specific phase of the cycle.

Results on physical differences During basketball workouts were found in the study of the Spanish research group, which observed 14 professional basketball players during 14 workouts, monitoring the stage of the MC, classified as menstruation, proliferative, ovulation and luteal and other dependent variables were recorded, divided into two groups: internal load (IL) and external load (EL)(Arenas et al., 2023). in the study it was observed that the acceleration capacity is one of the variables that can be most appreciated among the various performance of basketball and, after analyzing the results obtained in the research, it was seen that it is also the main variable influenced by the MC, a further reason to consider the MC when planning the

training of the players and get the least possible decrease in performance.

From the results presented in the study we can speculate that the main differences are in the accelerations and decelerations that athletes perform, as well as the explosive distance covered, while during the ovulation phase, higher values of external load are found, while in the late follicular phase the maximum intensity recorded in the previously highlighted variables was observed.

The MC has proven to be a performance conditioner (Dokumacı et al., 2019; Julian et al., 2017). Indeed, the worst results should be found in the late luteal phase and early follicular phase because there is a variation in hormone levels, both progesterone and estrogen (Jacobson & Lentz, 1998).

1.6 Lack of studies in scientific literature

The examination of literature across diverse topics has revealed the existence of certain deficiencies and limitations, some of which are mitigated by the aims outlined in the thesis and presented in table 1.

Table 1. The main deficiencies of previous studies on the topics relevant to the thesis

Lack of studies in the scientific literature		
Topic	Previous studies	Gap
Performance variables in foreign and national female players associated playing position and team quality	Zhai et al. (2020) Moreno et al. (2013) Sampaio et al. (2006) Paulauskas et al. (2018)	No previous studies regarding differences between foreign and national female basketball players
A comprehensive understanding of basketball players' performances by investigating the physical, perceptual, contextual, and technical-tactical variables	Martin et al. (2018) McNulty et al. (2020) Triguero et al. (2021) Stachoń (2016)	No previous studies with a comprehensive approach, examining the associations between key performance indicators and physical and perceived demands, menstrual cycle phase, perceived recovery, and game-related contextual factors among professional, female basketball players during official games
Information regarding the short-term effects of schedule congestion on the home advantage in professional female basketball clubs	Ibañez et al. (2009) Xing et al. (2023) Madrigal & James (1999) Steenland & Deddens (1997)	No previous studies observing the home advantage influence on different rest days in professional female basketball clubs

1.7 Aims of the Thesis.

Based on the above discussions, the main aim of the PhD thesis is to explore the training and match performance demands of Female basketball players considering game-related statistics, contextual factors, physical indicators, and the menstrual cycle. Specifically, the studies mainly focus on investigating the key performance indicators and collective playing style on European female basketball competition. The effect of contextual variables (game location, team quality, and opponent quality) was also taken into consideration in the analysis. To implement our purpose, the thesis was driven by the following three research aims:

(1) To comprehensively investigate and analyse variations in game-related statistics and performance metrics among national and foreign basketball players participating in a highly competitive women's league, the Euro League. This examination is conducted with a specific focus on playing positions and team proficiency levels, providing insights into how these factors influence player contributions and overall team success.

(2) To explore the multifaceted impact of various factors on the performance of female basketball players during official competitions. The research delves into the interplay between physical and perceptual demands, menstrual-related discomfort, recovery from exertion, and contextual game-related aspects to gain a comprehensive understanding of how these variables collectively influence player performance in the women's basketball arena.

(3) To gain insights into the repercussions of fixture congestion periods on the performance of top-level female basketball teams. This will be accomplished by analyzing game-related statistics from individual games within a competitive season, while considering factors such as the competition period, the number of games per week, and the type of competition. Through this comprehensive examination, we aim to better understand how fixture congestion impacts the game-related statistics of elite female basketball teams.

1.8 Structure of the Thesis

The structure of this PhD thesis was meticulously organized as follows: Chapter 1 served as a comprehensive introduction to the research. Chapters 2 to 4 were dedicated to presenting the methodologies employed and the principal findings for each of the three research objectives of this thesis. Chapter 5 offered a comprehensive discussion that delved into the outcomes and implications of each research objective. Chapter 6 was reserved for overarching conclusions that synthesized the key findings and contributions of this PhD thesis. The specific objectives of this PhD thesis were delineated into three interconnected segments. The first segment involved an in-depth examination of existing studies and literature. This section laid the scientific and technical foundation for comprehending the subsequent chapters' research. The next section was dedicated to elucidating the methodologies employed in Chapter 2, offering a detailed insight into the research processes. In Chapter 3, the research findings were presented, encompassing three primary investigations: (i) An exploration of disparities in game-related statistics and performance between national and foreign female basketball players in the elite EuroLeague. This analysis was conducted with a focus on playing position and team ability; (ii) A study examining the impact of physical and perceptual demands, menstruation-related pain, recovery, and contextual factors on the performance of female basketball players during official competitions. (iii) An investigation into the repercussions of fixture congestion, dissecting game-related statistics in individual matches played within a competitive season. This analysis considered variables such as the competition period, games per week, and the nature of the competition, specifically in elite female basketball teams. Chapter 4 is devoted to the discussion of the results presented, while in Chapter 5 some final conclusions of the research are considered.

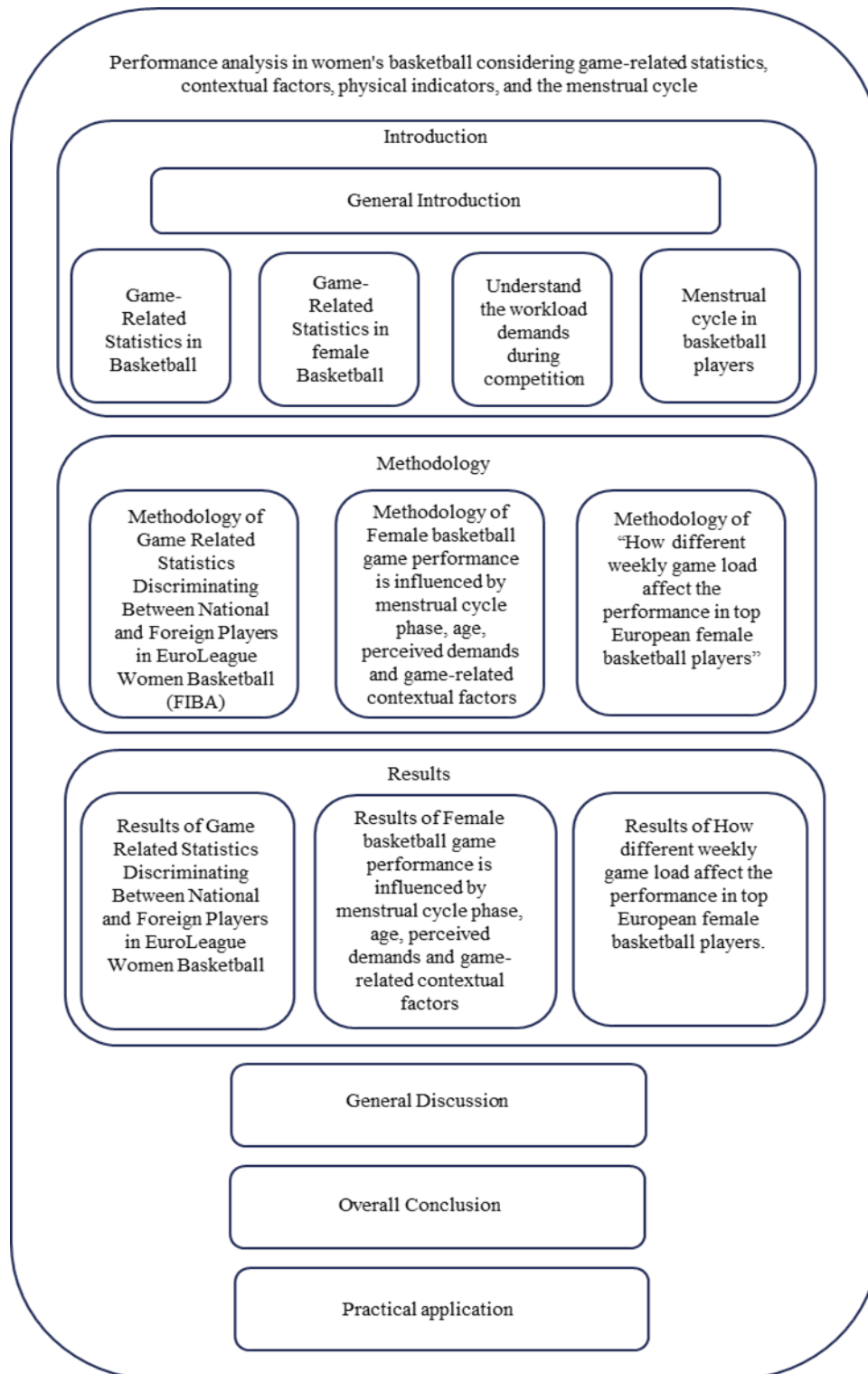


Figure 2. Schematic representation of the thesis

Additionally, the above sections have been specifically written for publication in scientific

journals to which they were submitted. The detailed information of each section with publications as listed in Table 2 below. All of the citations and references have been presented in American Psychological Association (APA 7th) referencing format using a single bibliography at the end of thesis.

Table 2. Articles submitted for publication in scientific journals

PhD thesis Aim	Title	Journal	JCR IF	Status
1	Game Related Statistics Discriminating Between National and Foreign Players in EuroLeague Women Basketball	International journal of environmental research and public health	4.132 Q1	Published
2	Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors	Journal of Sports Sciences	3.949 Q1	Published
3	How different weekly game load affect the performance in top European female basketball players	Chaos, Solitons & Fractals	9.922 Q1	Finishing the paper

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CHAPTER 2

Methodology

Chapter 2 Methodology

In order to provide a clear definition, explanation, and rationale for each aim of the thesis, the methodology section was split into 3 main sections focused on each aim respectively. Firstly, as data provider for the information from FIBA database, the first section display the methodology part of the study “Game Related Statistics Discriminating Between National and Foreign Players in EuroLeague Women Basketball (FIBA).” (Aim 1). Secondly, the analysis of physical and technical information during official games of a competitive women’s basketball season, considering the menstrual cycle, and components of effort and recovery through scales of perception (Aim 2). Lastly, the methodological part and analysis of the data provided by a competitive season of the teams that participated in the highest international championship, the Euroleague, considering the days of rest between the matches and the home advantage (Aim 3). Therefore, the following sections try to clarify the methodology used in each section of the PhD thesis.

2.1 Methodology of Game Related Statistics Discriminating Between National and Foreign Players in EuroLeague Women Basketball (FIBA).

2.1.1 Participant and data from FIBA database.

This study constituted a retrospective analysis that relied on publicly available data sourced from the 2016–2017 season of the FIBA Women's EuroLeague. It's worth noting that the data obtained through this methodology has exhibited good reliability in various contexts (Sampaio et al., 2008; Tabachnick & Fidell, 2007). The dataset for this analysis encompassed all games from the initial group phase, totaling 112 games. From these games, an array of game-related statistics was meticulously gathered, including 2- and 3-point field-goal shots (both successful

and unsuccessful), free-throw shots (both successful and unsuccessful), defensive and offensive rebounds, blocks, assists, fouls, steals, turnovers, and minutes played. These metrics have been routinely examined in prior studies focusing on basketball player and team performances (Hoffer & Freidel, 2013; Sampaio et al., 2010).

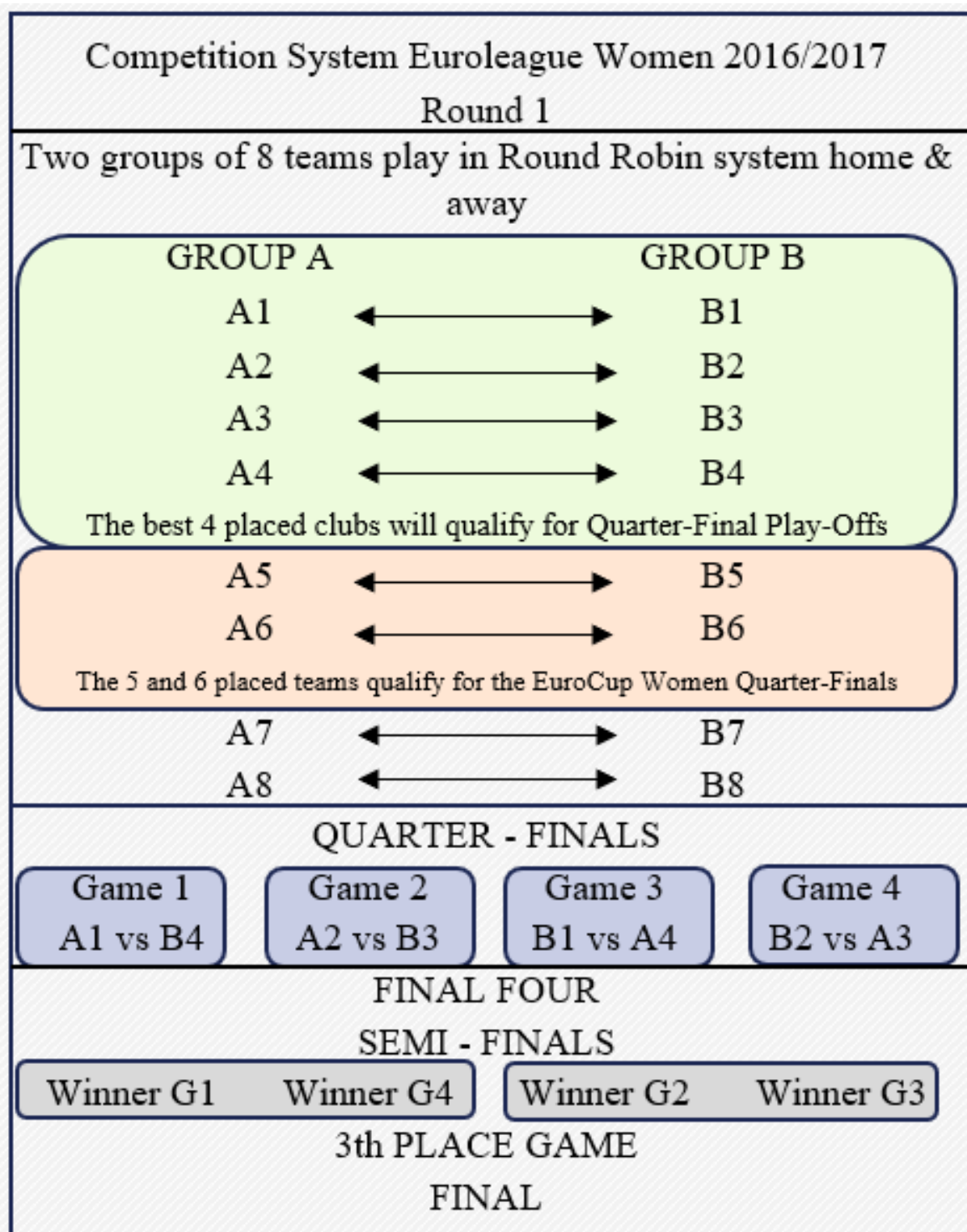


Figure 3. Competition System in EuroLeague Women 2016/2017

To categorize the players, a binary distinction was made between national players, referring to athletes representing a club from their own nationality's national competition, and foreign players, denoting athletes competing for a club in a national competition different from their own nationality's. Among the 200 players across the 16 women's Basketball Euroleague teams, 119 were categorized as national players, constituting 59.5% of the total, while 81 were identified as foreign players, accounting for 40.5% of the total player pool. Within the 112 games analyzed in this study, resulting in 2,225 player observations, 1,159 observations pertained to national players (52.1% of the total), while 1,066 observations were attributed to foreign players (47.9% of the total).

Further categorization was done based on playing positions, yielding the following breakdowns:

- For Guards: 943 player observations, 528 from national players (56.0% of the total) and 415 from foreign players (44.0% of the total).
- For Forwards: 539 observations, with 287 from national players (53.3% of the total) and 252 from foreign players (46.7% of the total).
- For Centers: 743 observations, consisting of 344 from national players (46.3% of the total) and 399 from foreign players (53.7% of the total).

Moreover, the assessment of team ability was carried out by classifying the sample into four distinct groups using a k-means cluster analysis. This categorization was based on the winning percentage of each team during the competition, with the four groups being defined as poor ($11.2 \pm 3.4\%$), low ($42.9 \pm 6.5\%$), medium ($65.5 \pm 6.6\%$), and high ($93.7 \pm 6.0\%$) [winning % = (games won/total games) * 100]. This segmentation allowed for a comprehensive examination of how team ability, as determined by winning percentages, intersects with player

nationality and position in the context of female basketball performance within the EuroLeague.

2.1.2 Statistical analysis.

The study employed a structured analytical approach to examine the differences in player performance between national and foreign players within the EuroLeague, considering various game-related statistics. Here's a step-by-step breakdown of the methodology:

1. Normality Assumptions Check: To begin, normality assumptions were assessed for each group of players in each condition (national vs. foreign) using the Kolmogorov-Smirnov test. This preliminary step ensured that the data met the assumptions necessary for subsequent statistical analysis.

2. Linear Regression Model: A linear regression model was then utilized to quantify each player's contribution to their team's performance for each game-related statistic. The model took the following form:

$$\text{Variable } x = \beta_0 + \beta_1 * \text{Player's performance variable } x + \epsilon_i,$$

In this equation, β_0 represents the intercept, β_1 signifies the impact of each predictor independent variable, and ϵ_i stands for the disturbance term. This approach allowed for the assessment of how each player's individual performance influenced specific game-related statistics.

3. Adjustment for Player Count: Following the linear regression analysis, the predictor model was adjusted to account for the number of players on the court at a given time, which is typically 5 players. The constant (β_0) was divided by 5 in each model to align with the number of players on the court simultaneously.

4. Discriminant Analysis: The study then turned to discriminant analysis to explore each player's contribution to the team. This analysis sought to identify the game-related statistics that most effectively distinguished between national and foreign players, taking into consideration

team ability. Specifically, variables with structural coefficients (SC) above $|0.30|$ were identified as those contributing most significantly to the differentiation between national and foreign players.

5. Validation: To validate the results of each analysis, a leave-one-out classification models process was employed. This approach helps ensure the robustness and reliability of the findings.

6. Statistical Software: All statistical analyses were performed using PASW Statistics 20 software, which is commonly known as SPSS Inc., based in Chicago, IL, USA.

7. Statistical Significance: The level of statistical significance was set at $p < 0.05$, indicating that findings with a probability of occurring by chance lower than 5% were considered statistically significant.

2.2 Methodology of Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors.

2.2.1 Participant.

For this study, we enlisted the participation of 11 adult female professional basketball players, whose characteristics are as follows: their average age was 20.6 ± 2.7 years; they had an average height of 178.3 ± 7.5 cm; their body mass averaged 73.6 ± 8.7 kg. These athletes possessed a playing experience of 12.9 ± 3.5 years. Regarding their playing positions, the group was comprised of 5 backcourt players and 6 frontcourt players.

Notably, these athletes are considered highly trained, competing at the national level in Lithuania's Women's Basketball League (Lietuvos Moterų Krepšinio Lyga or LMKL), which represents the highest echelon of national competition in the sport. Prior to the commencement of data collection, all players were thoroughly briefed on the data collection procedures, and they willingly provided their informed consent to participate in the study.

2.2.2 Data from the databank of the leagues.

We employed a descriptive, longitudinal research design for this study. The monitoring procedures commenced in September 2019 and continued until late January 2020, spanning a total duration of 14 weeks. Over this period, we scrutinized and evaluated 12 official games from the Lietuvos Moterų Krepšinio Lyga (LMKL). These games were typically scheduled once a week. Additionally, the team's weekly training regimen included 5 team-based training sessions, each lasting between 80 to 120 minutes, and 2 physical training sessions, each lasting approximately 60 minutes.

Throughout this extensive monitoring period, we amassed a substantial dataset comprising 120 individual data points, all pertaining to official games, as part of our comprehensive analysis.

2.2.3 Menstrual cycle information.

To determine the menstrual cycle phase for each player, we relied on the reported commencement date of menstruation. With this information at our disposal, we employed a reverse calculation method to ascertain the specific menstrual phase in which each player was situated during each official game. In this calculation, we designated days 1 to 14 as the follicular phase and days 15 to 28 as the luteal phase, adhering to established conventions in menstrual cycle classification. This approach allowed us to align the players' menstrual phases with the timing of the official games for our analysis (McNulty et al., 2020).

2.2.4 Recovery scale, external and internal load methodology.

On the morning of each game-day, players assessed their level of menstruation-related pain using a numerical scale ranging from 0 to 10 (Pathak et al., 2018). Players were given specific

instructions to report their pain levels solely in relation to menstruation-related symptoms. This pain scale ranged from 0, indicating "no pain," to 10, representing "maximum pain."

Furthermore, in addition to assessing pain, players were also requested to gauge their perceived level of recovery using a modified 10-point scale known as the TQR Scale (Sansone et al., 2018, Sansone et al., 2021). This particular variable was denoted as "TQRpre," signifying the players' perceived recovery levels before entering into competition.

To assess the physical demands during competitive games, each player was equipped with a microsensor (Catapult S5, Catapult Innovations, Australia), positioned at the upper back beneath their sports gear. The metric PlayerLoad™ per minute (PL*min⁻¹) was utilized as an indicator to gauge the external intensity of the game for each player (Fox et al., 2021).

Within the window of 15 to 30 minutes following the conclusion of each game, players provided their Ratings of Perceived Exertion (RPE) for that particular game. This assessment was conducted using the Foster modified CR-10 scale (Foster et al., 2001).

2.2.5 Game-related statistics.

Game performance was assessed by collecting game-related statistics from the official league website (<https://moterulyga.lt/>). Consistent with prior research (Conte & Lukonaitiene, 2018; Leicht et al., 2017b; Sansone et al., 2021), the selected game performance indicators encompassed the following stats: eFG%, which was computed using the formula (field goals made + 0.5 * 3-point field goals made) divided by field goals attempted; total rebounds (REB); turnovers (TO); and Performance Index Rating (PIR). It's worth noting that Performance Index Rating (PIR) is a widely adopted metric in FIBA basketball and has also been employed in previous basketball research studies (Garcia et al., 2022; Sansone et al., 2021).

PIR is computed using the following formula:

(Points+Rebounds+Assists+Steals+Blocks+Fouls Drawn)– (Missed Field-Goals+Missed Free-

Throws+Turnovers+Shots Rejected+Fouls Committed).

With the exception of eFG%, the chosen performance indicators were adjusted for playing time. This normalization ensured that the metrics considered the player's contributions relative to the amount of time they spent on the court. For example, a PIR of 10 achieved during 20 minutes of gameplay would be normalized to 0.5, and 3 turnovers in 30 minutes of gameplay would be normalized to 0.01.

In light of their significance to the study's objectives, contextual variables were taken into account. This included factors such as the game's location (home or away) and its outcome (win or loss). Furthermore, the score differential of the game was factored in to categorize it as either close (1-7 points), balanced (8-19 points), or unbalanced (>20 points). These contextual variables were considered to provide a comprehensive understanding of the games and their potential impact on player performance (Conte & Lukonaitiene, 2018; Leicht et al., 2017b). Additionally, the opponent's calibre was assessed, categorizing them as either better (top 6 ranked teams) or worse (bottom 6 teams) based on the final league classification. This evaluation aimed to factor in the strength of the opposition and its potential influence on player performance.

2.2.6 Statistical analysis.

The analyses were conducted using SPSS version 26.0 (IBM, Chicago, IL). Initially, separate linear mixed models were employed, with one model dedicated to each of the game performance variables under consideration (eFG%, REB, TO, PIR). These models aimed to assess the impact of pre-game conditions, in-game demands, individual characteristics, and contextual factors on game performance.

Subsequently, after the initial models, second linear mixed models were constructed to examine interaction effects for each dependent variable. These models considered only those variables

that exhibited a significant main effect on the respective dependent variables in the initial model. Significance was established at $p \leq 0.05$. The outcomes of the mixed linear models are presented as F and p values, while descriptive data is reported as mean $\pm$ standard error (SE).

Post-hoc pairwise comparisons were conducted and adjusted using the Bonferroni correction to account for multiple comparisons. Effect sizes (ES) were also calculated utilizing Cohen's d and interpreted as follows: 0.2 (trivial), 0.2–0.6 (small), 0.6–1.2 (moderate), 1.2–2.0 (large), and 2.0 (very large) (Hopkins et al., 2009).

2.3 Methodology of “How different weekly game load affect the performance in top European female basketball players”.

2.3.1 Data.

The sample was composed of full-season games of all teams ($N = 16$) participating in Euroleague Women 2021/2020 season. A total of 225 games were considered from full-season competitive phase which lasted from September 25, 2021 and May 23, 2022. Since each team must participate in both the Euroleague and national leagues and the schedules of the national leagues are different, the time of inter-match recovery period was calculated by subtracting the date of the previous National League or Euroleague match from the date of the Euroleague match. All breaks of more than seven days were considered seven days, including the first game of the season for each team and the mid-season break periods over 7 days. The data were retrieved from open-access Euroleague website statistics (available at <https://basketball.eurobasket.com/>). Institutional Review Board approval was not a requirement for this investigation, as the data was collected through public access web databases which disclose no individual health information.

2.3.2 Statistical Analyses.

Two Bivariate Poisson regression model have been proven for modeling basketball games considering the points scored by each team follows a Poisson distribution (Higgs & Stavness, 2021; Martín et al., 2016; Ruiz & Cruz, 2015). Such models take the general from

$$X_i \sim \text{Poisson}(\lambda_{1i})$$

$$Y_i \sim \text{Poisson}(\lambda_{2i})$$

$$\log(\lambda_{1i}) = \mu + \text{home}_k + \text{att}_{1[i]} + \text{def}_{2[i]}$$

$$\log(\lambda_{2i}) = \mu + \text{att}_{2[i]} + \text{def}_{1[i]}$$

Where X_i is the observed points scored in game i by the home team and Y_i is the points scored by the away team. The μ is the intercept term for expected log points throughout the season. Home advantage is represented by home_k with the k indicating different break days.

The offensive and defensive strengths of the two teams are represented by att and def . The nested indexes $1[i]$ and $2[i]$ identify the teams playing at home and away respectively and mean the multi-level nature of these parameters as they are modelled as exchangeable from a common distribution.

In formula (1), the points expectation of home team is a linear combination of the home advantage under different rest periods plus the home team's offensive strength and the away team's defensive strength. Conversely, the away team's points expectation is a linear combination of the away team's offensive strength and the home team's defensive strength with the home advantage parameter noticeably missing. The logarithm sign indicates that intercept

representing the logarithm of the overall average of points scored with $\exp(\mu)$, $\exp(home_k)$, $\exp(att_{1[i]})$, and $\exp(def_{2[i]})$ representing multiplicative increases or decreases to the average points scored to determine the expected points scored for an individual game.

For example, a home advantage parameter of $home = 0.05$ would result in multiplying the average points scored by $\exp(0.05) \approx 1.05$, which can be interpreted as an increase of about 5% in expected points scored by the home team in a game between teams with relative offensive and defensive strengths $att_{1[i]}$ and $def_{2[i]}$, respectively.

The Bayesian approach need to specify suitable prior distributions for all random parameters in the model. The prior distributions for parameters in our model are:

$$\mu \sim Normal(\theta, \sigma^2)$$

$$home \sim Normal(0, 1)$$

$$att \sim Normal(0, \sigma_{att})$$

$$def \sim Normal(0, \sigma_{def})$$

$$\sigma_{att} \sim HalfNormal(1)$$

$$\sigma_{def} \sim HalfNormal(1)$$

where θ is the logarithm of the average points scored by away team, and σ^2 is the logarithm of the variance of points scored by away team. σ_{att} and σ_{def} are the variances of all team offensive and defensive strengths.

In formula (2), the home advantage was considered as linear combination of the rest days.

$$home = \beta_0 + \beta_1 * Day_k + \varepsilon$$

$$home \sim Normal(\beta_0 + \beta_1 * Days, \varepsilon)$$

$$\beta_0 \sim Normal(0,10)$$

$$\beta_1 \sim Normal(0,1)$$

$$\varepsilon \sim HalfCauchy(5)$$

The models are fit using PyMC3's NUTS sampler using 4 chains of 2000 iterations with 1000 tune steps for a result of 8000 samples from 12,000 total draws. It is standard practice to check convergence with the $\hat{R}$ statistic from (Brooks & Gelman, 1998). Each model fit produced $\hat{R}$ statistics of 1.00 with no divergences, $\hat{R}$ is a convergence diagnostic, which is recommended to have values around 1.00, is considered reliable a value less than 1.05.

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CHAPTER 3

Results

Chapter 3 Results

3.1 Section 1 (Aim 1) – Results of Game Related Statistics Discriminating Between National and Foreign Players in EuroLeague Women Basketball

The study provides a detailed analysis of the means and standard deviations for various game-related statistics, along with univariate differences between national and foreign players, categorized by playing position and team ability. The findings are presented in Tables 3–5.

Notably, the univariate analysis revealed that foreign players generally displayed higher values for most game-related statistics in comparison to national players across the Guard, Forward, and Center playing positions (refer to Tables 3–5). This observation suggests that foreign players exhibited superior performance in various aspects of the game, contributing to their advantage over their national counterparts in these specific game-related statistics.

Table 3. Descriptive results (M, mean; SD, standard deviation) of national and foreign Guards based upon poor, low, medium, and high team ability.

Variables	Team Ability									
	Poor					Low				
	National		Foreign		Sig.	National		Foreign		Sig.
	M	SD	M	SD		M	SD	M	SD	
Minutes	63082	35935	108453	26853	<0.01	75479	38092	95881	38527	<0.01
% Successful 2 pt	9.24	2.37	12.94	3.38	<0.01	10.42	2.94	11.37	3.53	<0.01
% Unsuccessful 2 pt	17.10	1.63	14.24	2.39	<0.01	16.57	1.69	15.79	2.29	<0.01
% Successful 3 pt	12.10	2.19	12.86	2.95	0.04	12.62	2.71	14.18	3.74	<0.01
% Unsuccessful 3 pt	14.03	0.26	14.02	0.30	0.70	14.08	0.24	13.87	0.33	<0.01
% Successful free throws	12.12	0.75	13.78	2.03	<0.01	12.53	1.14	13.43	1.88	<0.01
% Unsuccessful free throws	13.87	0.04	13.89	0.07	<0.01	13.88	0.05	13.89	0.05	0.17
% Offensive rebounds	13.24	0.29	13.40	0.38	<0.01	13.29	0.31	13.34	0.35	0.15
% Assists	8.67	1.62	9.74	1.84	<0.01	9.02	1.46	9.79	1.89	0.00
% Steals	13.07	0.80	13.76	1.26	<0.01	13.31	1.13	13.61	1.11	0.01
% Defensive rebounds	13.38	0.56	12.92	0.72	<0.01	13.30	0.63	12.96	0.72	<0.01
% Fouls	15.04	1.37	15.82	1.40	<0.01	15.06	1.30	15.16	1.28	0.44
% Turnover	14.49	1.03	15.04	1.11	<0.01	14.53	0.92	14.97	1.23	<0.01
% Blocks	13.71	0.41	13.54	0.61	0.02	13.69	0.51	13.61	0.58	0.13
Variables	Medium					High				
	National		Foreign		Sig.	National		Foreign		Sig.
	M	SD	M	SD		M	SD	M	SD	
	M	SD	M	SD		M	SD	M	SD	
Minutes	67214	29659	108157	22683	<0.01	67406	36273	73706	22327	0.22
% Successful 2 pt	9.68	2.39	11.79	4.41	<0.01	11.08	3.42	10.63	2.55	0.39
% Unsuccessful 2 pt	16.81	1.41	15.71	1.75	<0.01	16.68	1.59	16.84	1.16	0.51
% Successful 3 pt	12.39	2.27	13.60	3.05	<0.01	12.75	2.86	14.35	4.73	0.04
% Unsuccessful 3 pt	14.11	0.19	13.94	0.24	<0.01	14.06	0.24	14.05	0.32	0.93
% Successful free throws	12.54	1.20	13.50	1.95	<0.01	12.53	1.16	13.17	1.74	0.03
% Unsuccessful free throws	13.87	0.04	13.90	0.06	<0.01	13.87	0.03	13.88	0.04	0.47
% Offensive rebounds	13.30	0.29	13.37	0.35	0.11	13.20	0.17	13.27	0.29	0.13
% Assists	9.02	1.72	10.48	2.13	<0.01	8.84	1.23	9.41	1.38	0.02
% Steals	13.46	1.06	13.72	0.96	0.09	13.26	0.88	13.36	0.96	0.58
% Defensive rebounds	13.34	0.57	12.90	0.71	<0.01	13.55	0.43	13.14	0.76	<0.01
% Fouls	15.04	1.24	15.63	1.26	<0.01	14.46	1.14	14.81	1.11	0.08
% Turnover	14.45	0.78	15.14	1.11	<0.01	14.14	0.62	14.38	0.82	0.09
% Blocks	13.76	0.31	13.64	0.51	0.04	13.65	0.60	13.68	0.52	0.81

Table 4. Descriptive results (M, mean; SD, standard deviation) of national and foreign Forwards based upon poor, low, medium, and high team ability.

Variables	Team Ability									
	Poor					Low				
	National		Foreign		Sig.	National		Foreign		Sig.
	M	SD	M	SD		M	SD	M	SD	
Minutes	54963	23559	105630	13713	<0.01	70839	40331	93701	36665	<0.01
% Successful 2 pt	8.91	1.61	12.77	3.45	<0.01	10.38	3.64	13.15	4.37	<0.01
% Unsuccessful 2 pt	17.05	1.40	14.34	2.06	<0.01	16.79	1.85	15.62	1.96	<0.01
% Successful 3 pt	11.37	1.78	12.70	2.63	0.01	12.84	2.88	12.80	3.10	0.93
% Unsuccessful 3 pt	14.17	0.17	14.08	0.27	0.08	14.00	0.37	14.02	0.34	0.80
% Successful free throws	12.31	1.06	13.11	1.76	0.02	12.73	1.78	13.19	1.54	0.04
% Unsuccessful free throws	13.87	0.02	13.88	0.04	0.13	13.89	0.06	13.88	0.05	0.59
% Offensive rebounds	13.25	0.27	13.69	0.66	<0.01	13.41	0.43	13.66	0.54	<0.01
% Assists	7.99	0.79	8.44	1.21	0.07	8.20	1.14	8.72	1.17	<0.01
% Steals	12.76	0.41	13.45	0.67	<0.01	13.37	1.09	13.57	1.25	0.21
% Defensive rebounds	13.43	0.43	12.43	0.90	<0.01	13.08	0.92	12.94	0.82	0.24
% Fouls	15.43	1.31	16.09	1.24	0.04	14.86	1.24	15.45	1.33	<0.01
% Turnover	14.21	0.68	14.77	0.94	0.01	14.28	0.82	14.73	1.02	<0.01
% Blocks	13.67	0.78	13.31	0.76	0.06	13.56	0.63	13.37	0.87	0.07
Variables	Medium					High				
	National		Foreign		Sig.	National		Foreign		Sig.
	M	SD	M	SD		M	SD	M	SD	
	M	SD	M	SD		M	SD	M	SD	
Minutes	33258	18751	96918	33552	<0.01	31552	23689	111269	19188	<0.01
% Successful 2 pt	8.37	1.53	13.07	4.06	<0.01	8.51	1.75	15.33	4.93	<0.01
% Unsuccessful 2 pt	17.57	1.04	15.28	2.20	<0.01	17.98	0.88	14.20	1.99	<0.01
% Successful 3 pt	12.21	2.30	13.26	3.55	<0.01	11.89	2.14	13.38	2.79	<0.01
% Unsuccessful 3 pt	14.18	0.19	14.06	0.29	<0.01	14.19	0.16	14.07	0.20	<0.01
% Successful free throws	12.37	1.07	13.58	2.01	<0.01	12.27	0.84	14.13	1.99	<0.01
% Unsuccessful free throws	13.87	0.03	13.90	0.06	<0.01	13.87	0.03	13.91	0.05	<0.01
% Offensive rebounds	13.27	0.30	13.78	0.65	<0.01	13.30	0.33	13.69	0.72	<0.01
% Assists	7.74	0.62	8.49	1.05	<0.01	7.78	0.70	10.15	1.63	<0.01
% Steals	12.78	0.44	13.47	0.96	<0.01	12.79	0.57	13.93	1.27	<0.01
% Defensive rebounds	13.56	0.43	12.38	1.10	<0.01	13.48	0.48	11.87	1.11	<0.01
% Fouls	14.47	1.18	15.26	1.22	<0.01	14.14	1.07	15.38	1.08	<0.01
% Turnover	13.87	0.53	14.69	1.02	<0.01	13.81	0.37	14.86	0.96	<0.01
% Blocks	13.70	0.43	12.74	1.75	<0.01	13.71	0.42	13.13	1.32	<0.01

Table 5. Descriptive results (M, mean; SD, standard deviation) of national and foreign Centers based upon poor, low, medium, and high team ability.

Variables	Team Ability									
	Poor					Low				
	National		Foreign		Sig.	National		Foreign		Sig.
	M	SD	M	SD		M	SD	M	SD	
Minutes	23093	20769	99350	25994	<0.01	71115	34005	92214	29669	<0.01
% Successful 2 pt	8.06	1.18	14.78	4.22	<0.01	11.37	3.73	14.82	4.71	<0.01
% Unsuccessful 2 pt	17.78	1.10	14.78	2.06	<0.01	15.84	1.93	14.60	2.12	<0.01
% Successful 3 pt	10.82	0.49	11.74	2.33	0.02	11.66	2.11	11.65	2.26	0.94
% Unsuccessful 3 pt	14.30	0.04	14.14	0.28	<0.01	14.19	0.17	14.20	0.20	0.64
% Successful free throws	11.98	0.55	14.03	2.19	<0.01	12.77	1.41	13.27	1.83	<0.01
% Unsuccessful free throws	13.87	0.04	13.89	0.09	0.22	13.89	0.06	13.90	0.07	0.03
% Offensive rebounds	13.21	0.22	13.81	0.64	<0.01	13.51	0.47	13.80	0.77	<0.01
% Assists	7.47	0.31	8.31	0.95	<0.01	8.41	1.10	8.28	0.91	0.23
% Steals	12.77	0.47	13.15	0.79	0.01	13.32	0.99	13.28	0.97	0.69
% Defensive rebounds	13.70	0.43	12.17	1.17	<0.01	12.83	0.86	12.32	1.11	<0.01
% Fouls	14.65	1.33	15.43	1.15	<0.01	15.46	1.41	15.65	1.30	0.19
% Turnover	13.88	0.56	14.71	0.87	<0.01	14.52	0.89	14.62	0.92	0.28
% Blocks	13.73	0.37	12.79	1.57	<0.01	13.16	1.24	13.23	1.03	0.58
Variables	Medium					High				
	National		Foreign		Sig.	National		Foreign		Sig.
	M	SD	M	SD		M	SD	M	SD	
	M	SD	M	SD		M	SD	M	SD	
Minutes	51562	28634	97377	20977	<0.01	55396	24043	79901	21390	<0.01
% Successful 2 pt	11.05	3.87	16.23	4.47	<0.01	12.10	4.30	16.08	4.80	<0.01
% Unsuccessful 2 pt	16.64	1.39	14.52	2.18	<0.01	16.02	1.98	15.45	1.89	0.16
% Successful 3 pt	11.74	2.45	11.47	1.96	0.47	10.73	0.00	11.16	1.34	0.04
% Unsuccessful 3 pt	14.19	0.22	14.18	0.22	0.87	14.30	0.03	14.27	0.08	0.01
% Successful free throws	12.54	1.04	13.30	1.68	<0.01	12.69	1.16	13.58	1.92	0.01
% Unsuccessful free throws	13.88	0.06	13.92	0.08	0.01	13.90	0.07	13.89	0.05	0.54
% Offensive rebounds	13.37	0.32	13.96	0.74	<0.01	13.85	0.67	13.83	0.56	0.86
% Assists	7.73	0.60	8.66	1.10	<0.01	8.08	0.88	8.32	0.84	0.18
% Steals	12.84	0.47	13.35	0.91	<0.01	13.06	0.65	13.44	1.01	0.04
% Defensive rebounds	13.28	0.72	12.14	0.99	<0.01	12.84	0.90	12.64	0.79	0.25
% Fouls	14.87	1.35	15.11	1.31	0.28	15.29	1.47	15.30	1.39	0.98
% Turnover	14.05	0.63	14.66	0.82	<0.01	14.03	0.55	14.17	0.76	0.31
% Blocks	13.22	1.24	12.81	1.43	0.08	12.66	1.60	11.58	2.19	0.01

The study conducted discriminant analysis to identify the functions that effectively differentiated between national and foreign players. The results indicated that all discriminant functions were statistically significant for each team ability group, with a significance level of $p \leq 0.05$. The structural coefficients, which indicate the importance of different variables in the discrimination process, were computed for each playing position and team ability group and are

presented in Table 6.

Furthermore, the classification results for all discriminant functions were deemed good to very good, with accuracy values exceeding 69% for the correct classification of cases. This level of accuracy suggests that the discriminant functions were successful in distinguishing between national and foreign players across different playing positions and team ability groups. These findings underline the effectiveness of the discriminant analysis in characterizing the performance disparities between these two player groups (Gómez et al., 2009).

Table 6. Discriminant function structure coefficients (SC) and tests of significance for each game metric that differentiated foreign and national Guards, Forwards, and Centres, based upon poor, low, medium, and high team ability.

Variables	Guards				Forwards				Centers			
	Poor	Low	Med	High	Poor	Low	Med	High	Poor	Low	Med	High
	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC
Minutes	0.68	-0.52	0.84	0.21	0.70	0.55	0.91	0.72	0.90	-0.59	0.80	0.66
% Successful 2 pt	0.64	-0.29	0.34	-0.14	0.43	0.64	0.59	0.40	0.54	-0.74	0.51	0.53
% Unsuccessful 2 pt	-0.71	0.39	-0.39	0.11	-0.45	-0.57	-0.52	-0.53	-0.48	0.56	-0.47	-0.18
% Successful 3 pt	0.15	-0.49	0.25	0.35	0.17	-0.01	0.14	0.12	0.14	0.01	-0.05	0.27
% Unsuccessful 3 pt	-0.03	0.75	-0.45	-0.02	-0.12	0.03	-0.20	-0.13	-0.19	-0.04	-0.01	-0.36
Successful free throws	0.57	-0.60	0.34	0.37	0.16	0.26	0.29	0.26	0.32	-0.28	0.22	0.34
Unsuccessful free throws	0.21	-0.13	0.28	0.12	0.10	-0.07	0.22	0.18	0.07	-0.20	0.19	-0.08
Offensive rebounds	0.24	-0.14	0.13	0.25	0.26	0.47	0.39	0.15	0.32	-0.42	0.40	-0.02
% Assists	0.30	-0.46	0.42	0.39	0.13	0.42	0.34	0.41	0.30	0.11	0.41	0.17
% Steals	0.33	-0.27	0.14	0.09	0.36	0.16	0.36	0.25	0.16	0.04	0.28	0.27
Defensive rebounds	-0.36	0.49	-0.38	-0.56	-0.42	-0.15	-0.55	-0.40	-0.44	0.46	-0.54	-0.15
% Fouls	0.28	-0.08	0.26	0.29	0.14	0.43	0.26	0.23	0.19	-0.12	0.08	0.00
% Turnover	0.26	-0.41	0.40	0.29	0.20	0.45	0.39	0.31	0.30	-0.10	0.34	0.13
% Blocks	-0.17	0.15	-0.17	0.04	-0.13	-0.23	-0.29	-0.13	-0.21	-0.05	-0.13	-0.35
Eigenvalue	1.020	0.248	0.823	0.278	3.211	0.296	1.658	6.177	2.625	0.307	1.342	0.678
% of Variance	100	100	100	100	100	100	100	100	100	100	100	100
Canonical Correlation	0.711	0.446	0.672	0.467	0.873	0.478	0.79	0.928	0.851	0.484	0.757	0.636
Wilks' Lambda	0.495	0.801	0.548	0.782	0.237	0.772	0.376	0.139	0.276	0.765	0.427	0.596
Chi-square	129.409	92.869	108.705	30.215	86.262	54.932	122.18	206.948	133.941	101.884	116.588	43.455
df	14	14	14	14	14	14	14	14	14	14	14	14
Sig.	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Classification results %	83.9	70.0	81.1	69.7	100	73.8	91.0	99.1	92.0	70.8	84.9	80.6

In the analysis focused on Guards, foreign players were distinguished from national players based on several game-related statistics across all team ability clusters (poor, low, medium, and high), as outlined in Table 6. Specifically, the discriminating variables included % successful

free-throws, % defensive rebounds, and % assists. Foreign Guards tended to have higher percentages of successful free-throws and assists, along with lower percentages of defensive rebounds, in comparison to national Guards. Additionally, the variables % unsuccessful 2-point field-goals (with lower values for foreign players) and minutes played (with higher values for foreign players) were discriminatory factors between foreign and national Guards across most team ability clusters, except for the high-level cluster.

For the Forwards position, foreign players were distinguished from national players by % minutes played and % successful and unsuccessful 2-point field-goals across all team ability clusters, as indicated in Table 6. Foreign Forwards typically had higher percentages of minutes played and successful 2-point field-goals, along with lower percentages of unsuccessful 2-point field-goals, in comparison to their national counterparts. Moreover, in the low, medium, and high team ability clusters, foreign Forwards exhibited statistically higher values for % assists and % turnovers compared to national Forwards.

In the Center playing position, foreign players were differentiated from national Centers by % minutes played and % successful 2-point field-goals for all team ability clusters, as presented in Table 6. Foreign Centers generally had higher percentages of minutes played and successful 2-point field-goals. Additionally, foreign Centers exhibited lower percentages of unsuccessful 2-point field-goals and defensive rebounds compared to national Centers in the poor, low, and medium team ability clusters. Conversely, foreign players in the Center position displayed higher percentages of offensive rebounds in these same team ability clusters.

These findings illustrate the specific game-related statistics that played a significant role in distinguishing foreign and national players within each playing position across different team

ability clusters, shedding light on performance variations in elite female basketball within the EuroLeague.

3.2 Section 2 (Aim 2) – Results of Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors.

Table 7. provides descriptive data for the evaluated variables. The outcomes of the first mixed models for main effects are presented in Table 7.

Table 7. Descriptive data of measured variables	
	Mean and standard deviation
TQR _{pre}	5.5 ± 1.6
PL * min ⁻¹	8.6 ± 2.3
RPE	6.5 ± 2.1
PIR	0.3 ± 0.4
eFG%	39.6 ± 27.3
REB	0.2 ± 0.1
TO	0.9 ± 0.9
All data are reported in arbitrary units (AU)	

Concerning Performance Index Rating (PIR), the initial value (Intercept: -1.228437) indicates a baseline performance level. Age had a positive effect (estimate: +0.048), suggesting that older players tended to have better overall performances. Additionally, higher RPE scores had a

positive effect on PIR (estimate: +0.083), indicating that players reporting higher perceived exertion levels tended to have better overall performances. Notably, a trend emerged, showing better performances in games won (PIR: 0.321 ± 0.46) compared to games lost (0.111 ± 0.93) (mean difference: -0.210 ± 0.110 , ES: 0.26, small).

For effective field goal percentage (eFG%), the initial value (Intercept: -115.35) serves as a reference point. Both RPE (estimate: +5.688) and TQRpre (estimate: +3.056) had positive effects on eFG%, indicating that achieving higher levels of perceived exertion and experiencing better pre-game recovery were associated with improved shooting performances. Notably, better shooting performances were observed during the follicular menstrual phase (eFG: $39.780\% \pm 3.830$) compared to the luteal phase ($31.462\% \pm 3.875$) (mean difference: $8.318\% \pm 3.194$, ES: 0.28, small). Age also had a positive effect (estimate: +5.164), suggesting that older players tended to have better shooting performances. Additionally, eFG% was lower in close games ($22.465\% \pm 4.708$) compared to balanced ($46.463\% \pm 4.815$) (mean difference: $-23.997\% \pm 6.081$, ES: 0.75, moderate) and unbalanced ($37.935\% \pm 4.576$) games (mean difference: $-15.470\% \pm 4.041$, ES: 0.63, moderate).

Regarding total rebounds (REB), the initial value (Intercept: 0.34749) signifies a baseline level. More rebounds per minute were gathered in games won (0.196 ± 0.020) compared to games lost (0.111 ± 0.027) (mean difference: $+0.086 \pm 0.029$, ES: 0.50, small). Furthermore, there was a trend indicating that more rebounds were collected during the follicular phase (0.165 ± 0.21) compared to the luteal phase (0.134 ± 0.21) (mean difference: 0.31), although the effect size was trivial (0.19).

For turnovers (TO), the initial value (Intercept: 0.161054) represents a baseline level. Backcourt players accumulated more turnovers (0.101 ± 0.011) than frontcourt players (0.068 ± 0.011) (mean difference: $+0.033 \pm 0.012$, ES: 0.39, small). A negative performance trend for menstrual pain score before the game (estimate: +0.014) suggested that it increased turnovers ($p=0.054$).

Additionally, older players exhibited a trend for fewer turnovers (estimate: -0.0054).

Table 8. Main effects results

Factor	Performance variable			
	PIR	eFG%	REB	TO
Age	F= 10.045, p= 0.002	F= 40.848, p <0.001	F= 0.130, p= 0.729	F= 4.232, p=0.042
Playing position	F=0.015, p= 0.902	F= 0.002, p= 0.968	F= 3.314, p= 0.120	F= 3.824, p= 0.053*
Menstrual phase	F= 1.173, p= 0.191	F= 5.063, p=0.031	F= 4.966, p= 0.030	F= 1.675, p= 0.198
TQR	F=2.180, p= 0.143	F= 7.529, p=0.010	F= 3.291, p= 0.074	F= 0.128, p=0.721
PL*min ⁻¹	F= 0.963, p= 0.329	F= 2.820, p= 0.099	F= 18.821, p= 0.182	F= 0.136, p=0.713
RPE	F= 26.868, p<0.001	F= 40.101, p< 0.001	F= 1.529, p= 0.221	F= 0.130, p= 0.719
Game location	F= 0.006, p= 0.938	F=0.010, p= 0.920	F= 1.663, p= 0.205	F= 0.001, p= 0.993
Game outcome	F= 3.406, p= 0.068*	F= 0.334, p=0.566	F= 9.749, p= 0.002	F= 1.888, p= 0.172
Score differential	F= 0.444, p= 0.643	F= 7.874, p=0.001	F= 3.306, p=0.049	F= 0.128, p= 0.880
Opponent's level	F= 0.297, p= 0.587	F= 0.571, p= 0.455	F= 2.737, p=0. 110	F= 0.582, p= 0.447

In bold significant effects; * marks a trend

The second mixed models for interaction effects revealed significant interactions for both PIR and eFG%. Age*RPE positively influenced players' PIR (estimate: +0.003381, F= 25.609, p < 0.001). Regarding eFG%, significant interactions were found for menstrual phase and points differential (F= 122.064, p< 0.001), menstrual phase and age (F= 99.685, p <0.001), menstrual phase and RPE (F= 18.782, p< 0.001), points differential and age (F= 11.678, p< 0.001), age and TQRpre (F= 94.572, p < 0.001), age and RPE (F= 37.610, p <0.001), and TQRpre and RPE (F= 5.259, p= 0.024).

3.3 Section 3 (Aim 3) – Results of How different weekly game load affect the performance in top European female basketball players.

The distributions for the estimates of the home advantage parameters from formula (1) can be seen in figure 3 with the different days colored. The peaks of these distributions represent the most likely values for the home advantage parameter and their width represents the uncertainty in these estimates.

Formula 1:

$$X_i \sim \text{Poisson}(\lambda_{1i})$$

$$Y_i \sim \text{Poisson}(\lambda_{2i})$$

$$\log(\lambda_{1i}) = \mu + \text{home}_k + \text{att}_{1[i]} + \text{def}_{2[i]}$$

$$\log(\lambda_{2i}) = \mu + \text{att}_{2[i]} + \text{def}_{1[i]}$$

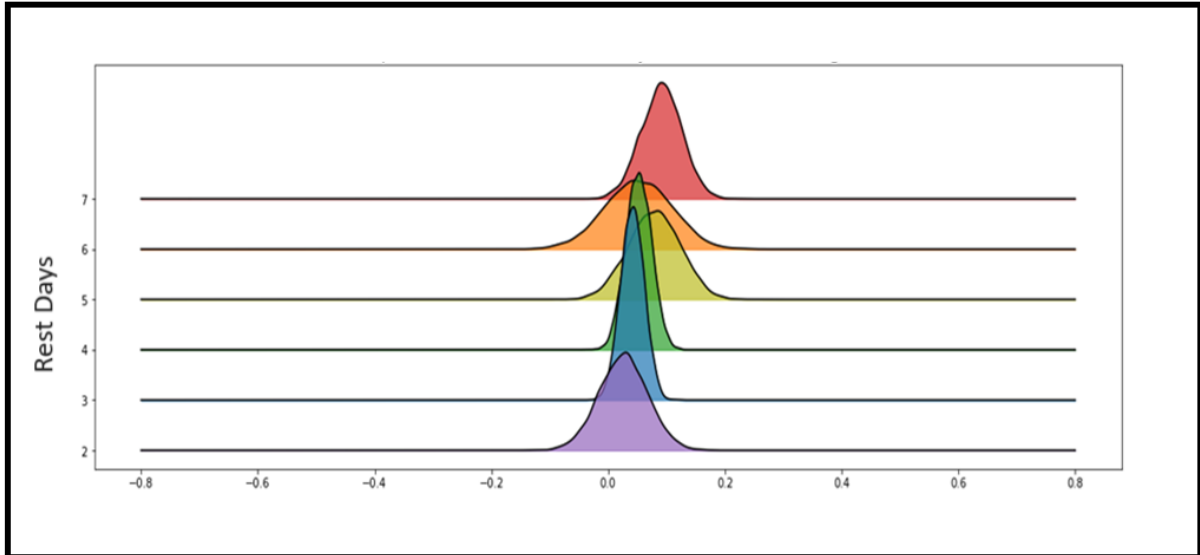


Figure 4. Impact of home team rest days on home advantage

For formular (2), the estimates of the regression coefficients about the rest day to home

advantage is presented in Table 8. The estimate of intercept represents when the home team play a game with zero rest day, the expected points scored by the home team will receive almost no bonus from the home advantage. Along with each additional day of rest for the home team, the expected score for the home team increases by 1.3%.

Formula 2:

$$home = \beta_0 + \beta_1 * Day_k + \varepsilon$$

$$home \sim Normal(\beta_0 + \beta_1 * Days, \varepsilon)$$

$$\beta_0 \sim Normal(0,10)$$

$$\beta_1 \sim Normal(0,1)$$

$$\varepsilon \sim HalfCauchy(5)$$

Table 9. Mean and sd of home and away rest days

	Mean	Sd	Hdi_3%	Hdi_97%	$\hat{R}$
Home					
Rest Day 3	0.017	0.045	-0.005	0.030	1.0
Rest Day 4	0.028	0.046			1.0
Rest Day 5	0.057	0.048			1.0
Away					
Rest Day 3	0.033	0.047			1.0
Rest Day 4	0.038	0.048			1.0
Rest Day 5	0.006	0.054			1.0

Table 9 showed the mean, standard deviation and 95% Credible interval (CI) of the posterior distribution for parameters in models.

The $\hat{R}$ for all parameters were between 1 and 1.01, indicating the models converged

successfully. Although the models estimated more than 100 parameters in the fitting process, to focus on the purpose of this study, only the parameters about rest days were reported in Table 9.

According to the means of parameters, comparing to play after 2 days' rest, the point score of the home team increased along with the increase in the number of rest days (0.016 for 3 days of rest, 0.027 for 4 days of rest, 0.056 for 5 or more days of rest). However, for the visitors, although there was still a higher probability of improvement with 3 and 4 days of rest, after 5 or more days of rest, the final point score of the away team was almost the same as with 2 days of rest.

PhD Thesis

D. Lorenzo Gasperi

CHAPTER 4

General Discussion

Chapter 4 General Discussion

The main aim of the PhD thesis is to explore the training and match performance demands of Female basketball players considering game-related statistics, contextual factors, physical indicators, and the menstrual cycle. Specifically, the studies mainly focus on investigating the key performance indicators and collective playing style on European female basketball competition. The effect of contextual variables (game location, team quality, and opponent quality) was also taken into consideration in the analysis. To pursue the research aims, the PhD thesis can be mainly composed by the three tightly studies, each section focusing on a different part of the female basketball performance analysis.

4.1 Summary and discussion of Main Findings

4.1.1 Section 1 (Aim 1) – Game Related Statistics Discriminating Between National and Foreign Players in EuroLeague Women Basketball

The primary objective of this study was to pinpoint the game-related statistics that effectively differentiate between national and foreign female basketball players, taking into account their playing positions and the competency of their respective teams. Broadly speaking, the results consistently demonstrated that foreign players exhibited superior performance across a spectrum of performance indicators, particularly excelling in terms of % minutes played, % successful 2-point field-goals, % successful free-throws, and % assists, when considering both team ability and playing position.

These findings hold paramount significance for coaches and team managers tasked with the intricate process of player recruitment. They offer invaluable insights into the strengths and areas for improvement of prospective recruits, offering a nuanced perspective that factors in nationality, preferred playing position, and unique performance attributes. Foreign players, by and large, made substantial contributions to their teams, standing out in collaborative plays and

their ability to draw fouls, as evidenced by their exceptional percentages of assists and successful free-throws. These aspects represent pivotal key performance indicators that wield considerable influence over success in women's basketball.

Furthermore, it's worth noting that the study unearthed interesting dynamics within the Guard position. While foreign Guards showcased an edge in certain areas, particularly excelling in successful free-throws and assists, it's pertinent to recognize that differences in 2- and 3-point field-goals for this playing position weren't consistently tied to nationality. This underscores the imperative for recruitment decisions concerning Guards to be rooted in a holistic assessment of skills such as shooting proficiency, ball-handling, teamwork, and playmaking ability, irrespective of the player's nationality.

A noteworthy distinction emerged in the realm of defensive rebounds, where foreign Guards generally recorded lower percentages compared to their national counterparts. This suggests a pronounced offensive orientation among foreign players in this position. Consequently, foreign Guards are often sought after for their offensive prowess, whereas national Guards might be valued for their defensive contributions.

Turning to playing time allocation, the study illuminated an intriguing pattern where foreign Guards bore a heavier load in lower-level teams compared to their national counterparts. This phenomenon is likely underpinned by the perceived higher regard for the abilities of foreign players and the greater financial investments made in them. In contrast, high-level teams appeared to rely less on foreign Guards, possibly due to the presence of quality national Guards, affording greater positional flexibility within the team.

Transitioning to the Forward position, foreign players consistently showcased superior 2-point shooting ability across all team ability clusters. This alignment with the significance of successful 2-point field-goals as a pivotal performance indicator distinguishing between winning and losing women's basketball teams underscores the indispensable role foreign

Forwards play on their teams. Moreover, foreign Forwards logged more playing time, signifying teams' heavy reliance on their contributions. However, it's pertinent to note that these foreign players also recorded higher percentages of assists and turnovers in both low and high team ability clusters. This suggests that while foreign Forwards undeniably made substantial contributions to team success, they also bore a slightly elevated risk of turnovers that could potentially impact team performance. Coaches should take this into consideration during the recruitment process.

In a similar vein, foreign Centers displayed heightened offensive prowess, boasting superior percentages of successful 2-point field-goals and more minutes on the court compared to their national counterparts. National Centers, on the other hand, excelled in defensive actions, particularly in terms of higher percentages of defensive rebounds and blocks, particularly in the high team ability cluster. This nuanced difference underscores the distinctive roles played by foreign and national Centers within the Euroleague Women's competition. It highlights the necessity for coaches and teams to thoughtfully weigh these factors when composing their rosters.

This study offers profound insights into the game-related statistics that set national and foreign elite female basketball players apart, all while considering various playing positions and team abilities. While the findings are rooted in an analysis of games from the initial phase of the Euroleague Women's competition, they offer a valuable foundation for future research exploring different competition phases and leagues across the globe. Additionally, conducting longitudinal studies that track performance differences over time would provide a comprehensive understanding of the enduring impact of national and foreign players on team success. Such insights will undoubtedly empower coaches to make well-informed recruitment decisions, thereby elevating the performance and success of women's basketball teams (Eschker et al., 2004; Ozmen, 2012).

This study has significantly enhanced our comprehension of the game performance of both foreign and national female basketball players. In particular, it sheds light on the superior performance of foreign Guards in terms of their % successful free-throws and % assists when compared to their national counterparts. These findings underscore the pivotal role that foreign players play in orchestrating collaborative actions and in drawing fouls, which are recognized as two of the primary key performance indicators contributing to success in women's basketball (Conte & Lukonaitiene, 2018; Gómez et al., 2013). A particularly intriguing observation arising from our study is the variability in differences concerning 2- and 3-point field-goals among Guards. This variance persists despite these offensive performance metrics being a focal point for this playing position, as highlighted in previous research (Hoffer & Freidel, 2013). What this suggests is that, within the Euroleague, Guards with similar and likely very proficient field-goal shooting abilities were recruited, regardless of their nationality.

On the contrary, foreign Guards exhibited a lower percentage of defensive rebounds compared to their national counterparts. This discrepancy indicates a greater offensive orientation among foreign players in contrast to the more defensively inclined approach of national players. Consequently, when considering the recruitment of foreign players to complement national ones and enhance team success, it is paramount to prioritize attributes such as shooting prowess, ball-handling, teamwork, and playmaking skills, as these are integral to building a well-rounded and successful team.

Moreover, the analysis unveiled that the variable % minutes played served as a key discriminator between foreign and national players, especially within the poorer to medium-level team ability clusters. This observation implies that teams performing at lower levels relied more heavily on foreign Guards to achieve success as opposed to their national counterparts.

This heightened reliance on foreign Guards in lower-level teams could be attributed to several factors. One possibility is the perceived higher regard for the abilities of foreign players among

coaches and teams (Eschker et al., 2004). Additionally, it could be linked to the greater financial investments typically made in foreign players (Ozmen, 2012). These investments likely stem from the belief that foreign players can significantly elevate a team's performance, particularly in scenarios where there may be limited local talent available.

Conversely, within high-level teams, there was no significant difference in % minutes played between national and foreign Guards. This absence of distinction suggests that high-level teams may have the luxury of choosing from a pool of talented national Guards, reducing their reliance on foreign players in this position. This dynamic underscores the multifaceted considerations that come into play when building a successful basketball team, ranging from player ability to team financial resources. Furthermore, this disparity in % minutes played may also be influenced by specific performance metrics. For instance, national players in lower-level teams displayed a poorer shooting percentage, particularly in terms of % unsuccessful 2-point field-goals, while foreign players in these clusters exhibited a greater proficiency in 3-point shooting (as indicated in Table 3). Both these metrics hold substantial significance in the context of female basketball success (Gómez et al., 2006; Sampaio & Janeira, 2003). The combination of these factors might have led lower-level teams to rely more heavily on foreign Guards.

In contrast, at the high team ability level, no significant differences were observed in % minutes played between national and foreign Guards. This suggests that top-tier teams may prioritize recruiting quality national Guards, thus reducing their dependence on foreign players in this particular role. This strategic approach offers teams greater flexibility in shaping their roster, which, in turn, contributes to their overall success.

In summary, these findings underscore the crucial role played by foreign Guards across all team ability clusters, with a heightened reliance on these players in lower-level teams, especially when national players may struggle with key performance metrics. High-level teams, on the other hand, may prioritize quality national Guards, allowing for a more versatile approach to

team composition. These dynamics highlight the complex and multifaceted nature of assembling a successful basketball team.

The analysis of Forwards in this study highlighted several key factors that underscore the significance of foreign players in team success. Specifically, foreign Forwards exhibited superior 2-point shooting performance compared to their national counterparts across all team ability clusters. This aligns with the recognized importance of successful 2-point field-goals as a fundamental performance indicator that distinguishes winning from losing female basketball teams (Conte & Lukonaitiene, 2018; Gómez et al., 2013).

Furthermore, foreign Forwards consistently accumulated more playing time than national Forwards across all team ability clusters, emphasizing the heavy reliance placed on foreign players in this position by teams striving for success. This reliance was also reflected in the higher percentages of assists contributed by foreign Forwards. Their ability to set up scoring opportunities for their teammates is a crucial aspect of team play in basketball and further highlights the value of foreign Forwards to team success (Gómez et al., 2008; Csataljay et al., 2009; Ibáñez et al., 2009; Leicht et al., 2017b; Sampaio & Janeira, 2003).

However, it's noteworthy that foreign Forwards also had a higher percentage of turnovers compared to national players, particularly in low to high team ability clusters. While low turnovers are considered essential for distinguishing between winning and losing elite female teams (Conte & Lukonaitiene, 2018; Leicht et al., 2017b), the current results suggest a potential risky behavior among foreign players, which could potentially impact team performance and success. Coaches should be mindful of this when evaluating and recruiting foreign Forwards, considering their offensive strengths alongside the need for improved ball security to maximize overall team performance.

In summary, foreign Forwards have consistently demonstrated their importance to team success, excelling in 2-point shooting, accumulating more playing time, and actively

contributing to team assists. However, coaches should be aware of the slightly elevated turnover rates among foreign Forwards and weigh their offensive prowess and facilitative abilities against the potential for turnovers when making recruitment decisions.

The findings pertaining to Centers mirror those of the other playing positions, underscoring the importance of foreign players and their unique contributions to team success. Foreign Centers consistently demonstrated higher percentages of minutes played, successful 2-point field-goals, and offensive rebounds when compared to their national counterparts, indicative of their enhanced offensive capabilities.

Conversely, national Centers exhibited less proficiency in offensive aspects, as evidenced by a greater percentage of unsuccessful 2-point field-goals. However, they excelled in defensive actions, particularly in terms of defensive rebounds and blocks, with these differences being most pronounced in lower team ability clusters (poor-medium). This suggests that national Centers embraced a more defensive-oriented role within their teams.

The observed distinctions between foreign and national Centers reinforce the idea that these players had distinct primary roles and responsibilities within the Euroleague Women's competition. While both national and foreign Centers align with the primary offensive and defensive actions expected of Centers (Gómez et al., 2013; Hoffer & Freidel, 2013), foreign Centers demonstrated a more assertive offensive presence, while national Centers leaned towards defensive contributions.

These results prompt coaches and teams to carefully consider the role of foreign and national Centers when developing their team rosters. National players may benefit from competing against highly skilled foreign players with strong offensive capabilities, potentially leading to improvements in their own assertiveness and defensive skills (Alvarez et al., 2011). Additionally, the recruitment of national players could serve as a supplementary process aimed at complementing the skills and abilities of foreign players in the Center position (Eschker et

al., 2004).

In summary, the unique roles and contributions of foreign and national Centers in the Euroleague Women's competition emphasize the importance of considering these factors when building a successful team. The study findings offer valuable insights for coaches and teams seeking to optimize their rosters by capitalizing on the distinct strengths and capabilities of players in the Center position.

4.1.2 Section 2 (Aim 2) – Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors.

The performance of basketball players is a complex interplay of various factors, encompassing individual attributes, contextual elements, and the specific demands inherent to competitive scenarios. Given the multifaceted nature of these interactions, it becomes imperative for research to adopt a comprehensive approach, examining players' performances from various angles. The primary objective of this study was to investigate how the game-related statistics of professional female basketball players are influenced by a constellation of factors, including individual characteristics, contextual variables, menstrual cycle phases, and the exigencies of the game itself.

The key findings of this study are as follows:

1. External intensity, as represented by PL*min-1, did not exhibit a discernible effect on any of the key performance indicators under consideration.
2. Higher RPE scores were associated with improved overall PIR and enhanced eFG%, suggesting that players reporting heightened perceived exertion tended to deliver better performances in both aspects.
3. Players in the follicular phase of the menstrual cycle demonstrated superior eFG% and a

greater ability to collect rebounds. Conversely, the presence of menstrual-related pain was found to increase the occurrence of turnovers.

4. Reporting a higher level of recovery before the game was linked to improved eFG%, indicating that feeling more recovered prior to a game was associated with better shooting accuracy.

5. Notably, the analysis revealed numerous interaction effects, particularly in the realms of PIR and eFG%. These interactions underscored the intricate interplay among individual attributes, contextual factors, recovery status, menstrual-related variables, and perceived game demands. These multifaceted interactions underscore the necessity of considering these diverse factors collectively to gain a more comprehensive understanding, predict potential outcomes, and optimize players' performances effectively.

An essential objective of this study was to investigate whether game demands indicators could exert an influence on critical basketball performance metrics. In our analysis, we discerned that external intensity, represented by $PL \cdot \min^{-1}$, did not yield any discernible impact on the selected performance indicators. This finding aligns with the outcomes of two prior studies, which similarly demonstrated a lack of significant associations between the physical demands of games and various performance indicators in basketball.

These results collectively reinforce the notion that, at least within the scope of our study and in accordance with previous research, external intensity, as quantified by $PL \cdot \min^{-1}$, may not be the predominant determinant of key performance outcomes in basketball. Instead, it suggests that other multifaceted factors, encompassing individual attributes, contextual considerations, and the intricate dynamics of team play, may exert more prominent influences on the performance of basketball players. Our findings are in concurrence with the outcomes of two prior studies, which similarly found no discernible associations between the physical demands of basketball games and the selected performance indicators (Garcia et al., 2022; Palmer et al.,

2022). This alignment with previous research further underscores the notion that game-related physical demands, as measured in terms of external intensity, may not be the primary determinants driving key performance outcomes in basketball. It implies that other intricate and multifaceted factors, such as individual attributes and contextual dynamics, likely play more substantial roles in shaping the overall performance of basketball players. Indeed, specific prior research supports our findings. Specifically, Garcia and colleagues conducted a study that yielded overarching results indicating that game-related statistics did not exhibit any significant associations with physical demands. Furthermore, Palmer (2022) embarked on an investigation aimed at discerning whether the physical performances of female and male semi-professional players differed based on the game scenario, particularly focusing on scoring streaks or balanced phases.

Intriguingly, the findings from this study unveiled that there were no substantial disparities in physical indicators, even during distinct phases of the game characterized by scoring streaks or more balanced play (Palmer et al., 2022). These outcomes strongly imply that technical-tactical indicators held greater sway in influencing player performance. Consequently, it becomes evident that physical performances, at least in these contexts, do not seem to exert any discernible effects or relationships with the key performance indicators that define success in the realm of basketball.

Taking into account the internal load, our study unveiled a noteworthy positive impact of RPE on both PIR and eFG%. These findings are in line with the observations made by Garcia (2022), who also noted that players with higher internal loads, as measured by mean heart rate, tended to achieve higher PIR values across games.

This association underscores an intriguing aspect of player performance - the need for players to allocate more time on the court in order to attain higher physiological and perceived loads. In essence, it implies that players who engage in more strenuous physical exertion, as perceived

through RPE, are more likely to exhibit enhanced overall PIR and eFG%. This emphasizes the intricate relationship between exertion, performance, and time spent on the basketball court.

Therefore, considering that basketball coaches typically manage playing time by allocating more minutes to the most skilled and productive players on the team, in accordance with the significance of key performance indicators for achieving success (Gómez et al., 2006; Leicht et al., 2017b; Sampaio et al., 2006), it is plausible that these extended playing times, representing a higher external "dose" in terms of game participation, may ultimately lead to increased internal loads (Impellizzeri et al., 2018).

Notably, while the RPE score serves as a valuable indicator of training intensity, recent studies (Passfield et al., 2022; Weaving et al., 2020) have brought to the forefront a crucial observation. These studies underscore that RPE-derived calculations not only reflect training intensity but also encompass substantial information regarding the training volume.

An additional potential confounding factor related to internal loads, as previously identified in the basketball literature, is the outcome of the game. A study by Fox (2021) has revealed an intriguing observation: even when exposed to the same external intensity, basketball players tend to report lower Ratings of Perceived Exertion (RPE) in games they have lost compared to games they have won. This phenomenon is believed to be driven by the potential psychoemotional implications associated with the game's outcome.

Given that key performance indicators serve as discriminators of success in basketball, it is plausible that the higher RPE scores reported by players in our study could have influenced both PIR and eFG% through a potential mediating effect of the game's outcome. This suggests that the psychological and emotional impact of winning or losing games may have interplayed with RPE scores, further shaping player performance in complex ways.

To the best of our knowledge, this study represents the pioneering effort to explore the influence of menstrual cycle phases on game performance in female basketball players. Our investigation

revealed an intriguing pattern, wherein players exhibited eFG% during the follicular phase in comparison to the luteal phase. Furthermore, there was a notable trend suggesting that more rebounds were gathered during the follicular phase, although this trend was not statistically significant. It's worth noting that comparing our results with previous research focused on technical aspects of performance in basketball has proven to be challenging due to the limited availability of relevant investigations in this domain. This scarcity of prior research underscores the novel and pioneering nature of our study, shedding light on an area that had hitherto been relatively unexplored in the context of female basketball players and their menstrual cycle phases.

It's noteworthy to mention a recent meta-analysis on the topic of menstrual cycles and performance, which indicated only minor disadvantages in performance during the early follicular phase when compared to other menstrual phases (McNulty et al., 2020). However, it's essential to bear in mind that the hormonal mechanisms believed to influence performance primarily revolve around aspects like substrate utilization, anabolic processes, and inflammatory responses. These mechanisms may have a more direct impact on physical capacities rather than the technical performance aspects, such as those we analysed in our study. This distinction underscores the complexity of the relationship between menstrual cycles and performance in female athletes. While there may be subtle effects during certain phases of the menstrual cycle, these effects may not always translate into significant differences in technical aspects of performance, as observed in our study. It highlights the need for a more nuanced understanding of how hormonal fluctuations may impact various facets of athletic performance in female athletes.

Indeed, the study by McNulty and colleagues underscores an important consideration - the specific test or performance being evaluated can potentially yield varying results depending on the phase of the menstrual cycle (McNulty et al., 2020). This insight highlights the nuanced and

context-dependent nature of how menstrual cycle phases may influence athletic performance. Of particular interest in our study, we observed a trend suggesting a negative impact of menstrual-related pain on turnovers, with higher pain levels corresponding to an increase in turnovers (effect size: small). While this observation is intriguing, it's important to recognize that it remains a hypothesis, and we cannot definitively confirm it with existing evidence. However, this trend raises the possibility that the perception of pain may adversely affect an athlete's focus, mood, or decision-making processes, potentially leading to specific technical errors such as turnovers.

Collectively, our findings underscore the potential utility of monitoring the menstrual cycle phase and related symptoms for basketball practitioners. Given the observed associations with key performance indicators, it suggests that such monitoring could offer valuable insights for optimizing and tailoring training and game strategies to the unique needs and challenges that female basketball players may experience across different phases of their menstrual cycles.

In the context of pre-game recovery, our study revealed that players demonstrated improved shooting performances when they reported higher Total Quality Recovery before the game (TQRpre). Intriguingly, a separate study (Sansone et al., 2021) conducted in same field also identified positive effects of enhanced recovery, as indicated by higher TQRpre scores, on the PIR of male semi-professional players. This collective body of evidence suggests that a player's perception of their recovery status may serve as a valuable indicator for basketball coaches. It offers valuable insights into what can be expected from a player's technical performances during competition. In essence, monitoring and addressing players' perceptions of recovery can potentially play a pivotal role in optimizing their readiness and performance on the basketball court.

Examining individual characteristics in our study, we observed a notable positive effect of age on key performance indicators. Specifically, older players demonstrated higher PIR, superior

eFG%, and fewer TO. This observation is in line with the conventional understanding that athletic performance tends to peak a few years after reaching maturity and may subsequently decline (Allen & Hopkins, 2015). Interestingly, the findings from our study align with those of Zhang (2018), who conducted research in the context of the NBA. Their study suggested that NBA players who belong to more successful teams typically possess a higher level of experience, which often comes with age. Conversely, younger players were often found to be associated with weaker teams. This underscores the intricate relationship between age, experience, team success, and individual performance in the dynamic world of basketball.

Taking into account the relatively youthful age of our study's sample, with an average age of 20.6 ± 2.7 years, our observed results align logically with this demographic. It's entirely plausible that the younger players in our study may have had limited experience at the national and professional levels of basketball. Consequently, this relative lack of experience among the younger cohort could reasonably contribute to their comparatively poorer performance outcomes. This observation underscores the importance of acknowledging the developmental trajectory of athletes in sports like basketball, where experience and maturity can significantly influence individual and team performance outcomes. As these younger players gain more exposure and experience at higher competitive levels, we might anticipate their performance trajectories to evolve over time.

Prior research in the realm of basketball has consistently highlighted the significance of contextual factors in shaping basketball performance outcomes (Gómez et al., 2006; Sansone et al., 2021). Our study, in alignment with these observations, noted a trend toward lower Performance Index Rating (PIR) values in games that were lost (Sansone et al., 2021). This pattern had also been previously identified in the context of male basketball. Collectively, this suggests that PIR values are indeed closely associated with success in basketball competitions, serving as a reliable indicator of a team's performance. Additionally, our study unearthed an

intriguing observation, wherein players exhibited poorer shooting performance, as indicated by lower effective field goal percentages (eFG%), in close games. This phenomenon could potentially be attributed to the heightened psychological and technical-tactical demands that close games often entail.

Furthermore, we noted that our players were more adept at collecting rebounds in games that were won compared to those that were lost. This observation underscores the well-established and pivotal importance of controlling rebounds in achieving success in basketball games. It reaffirms the notion that securing possession through effective rebounding plays a significant role in a team's ability to secure victories on the basketball court (Gómez et al., 2006; Leicht et al., 2017b).

4.1.3 Section 3 (Aim 3) – How different weekly game load affect the performance in top European female basketball players.

The impact of rest periods on team performance, particularly in relation to HA, is a critical aspect explored in this study. The findings provide a deeper understanding of how various factors interact to influence game-related statistics and, consequently, the outcome of elite female basketball games.

The study reaffirms previous research (Entine & Small, 2008; Steenland et al., 1997) indicating that the effect of rest on team performance is non-linear. The positive influence of rest on performance reaches a peak and then decreases as the duration of rest increases. It's suggested that this phenomenon may be partly attributed to the fact that a significant portion of games in the national league and Euro-league involves less than ideal days of pre-game rest. Players may have adapted to the congested schedule, and extended rest periods can disrupt their physical rhythms and overall game performance.

The analysis of rest days for the home team yields interesting insights. The study reveals a

noticeable increase in performance, particularly in terms of points scored, after the second rest day, with further improvements observed up to five or more days of rest. These findings align with prior research conducted by Pedro T. Esteves, indicating that having one day of rest between games significantly enhances the likelihood of winning compared to playing back-to-back games (Esteves et al., 2020). Shooting efficacy-related statistics play a crucial role in distinguishing between different fixture congestion cycles, with games lost in back-to-back situations significantly exceeding expectations when fixture congestion is not considered.

In contrast, a study by Ibanez (2008) involving congested games did not find substantial differences in game-related statistics between games played in a one-day tournament with three consecutive matches (Ibanez et al., 2008). This suggests that accumulated fatigue may not significantly impair team performance across three consecutive games. These findings support the notion that unlimited player substitutions in basketball allow teams to maintain consistent performance levels.

The discussion also delves into the performance of the host team, which demonstrates improved scoring outcomes after three and four days of rest. On the fifth day, the results tend to resemble those observed after the second day of rest. These findings align with previous research (Steenland & Deddens, 1997) that emphasized the positive impact of having more than one day of rest between games. This effect tends to peak with three days between games and then gradually diminishes after four days of rest.

A significant contribution of this study is its examination of the effects of prolonged fixture congestion periods on game-related statistics. Three-point missed and attempted statistics emerge as key differentiators between fixture cycles. As the recovery period between games extends, there is a noticeable increase in the number of three-point shot attempts, particularly when transitioning from two days of rest to three or more days of rest. Although the number of successful three-point shots remains relatively stable across fixture cycles, the increase in

attempts is notable. This underscores the importance of three-point shooting in determining game outcomes, particularly in women's basketball. The study by Gómez (2006) further supports this argument by highlighting the significance of three-point field goals in determining game outcomes (Gómez et al., 2006). For players with less physical strength, such as younger players and women, the ability to make long-distance field goals becomes a critical discriminator between skill and physical conditioning.

Additionally, the discussion references a study by Xing (2023), which suggests differences in the time it takes for home teams and away teams to reach their performance peaks (Wang et al., 2023). Away teams tend to reach their peak performance about one day faster than home teams. This variation is attributed to differences in resting environments. Home teams can return to their own homes for rest, while away teams are limited to hotel accommodation. The unfamiliar sleeping environment in hotels, characterized by factors like noise, lighting, and bedding, can negatively impact sleep quality and, consequently, recovery time for away teams. The separation from families and familiar surroundings can also contribute to psychological and emotional fatigue among away team players, further affecting their game performance.

In conclusion, the study provides valuable insights into the complex interplay of rest, fixture congestion, and team performance in elite female basketball. It underscores the importance of managing rest periods effectively and highlights the critical role of three-point shooting in determining game outcomes. Strategies to minimize disruptions to sleep patterns during travel, especially for away teams, are emphasized, offering practical recommendations for optimizing performance in elite women's basketball.

4.2 Limitations

Throughout this PhD. thesis, there were a number of limitations associated with the aims that

should be addressed in further research:

(1) This aim represents a pioneering effort in analysing the distinctions in game-related statistics between national and foreign elite female basketball players, considering various playing positions and team abilities. While this novelty adds unique value to the existing body of knowledge, it also presents certain limitations that warrant consideration for future research directions.

Firstly, this part primarily focused on games from the initial phase of the Euro league Women's competition. While this phase offers valuable insights, future research could delve deeper by examining game-related statistics during the final competition phase. This is particularly relevant as game metrics have been reported to play a pivotal role in determining match success, and these metrics might differ significantly in the final stages of competition compared to the initial phases (Csataljay et al., 2009; Gómez et al., 2013; Leicht et al., 2017).

Secondly, it concentrated on the top European female basketball league, which provides insights into a specific basketball population. To gain a more comprehensive understanding of the global landscape, future investigations should consider examining other top leagues worldwide, such as the WNBA in the United States. Comparing statistics across different elite leagues could shed light on international variations in player performance and recruitment strategies.

Lastly, this study's analysis was based on one year of game statistics. To ascertain the stability or evolution of differences between national and foreign players over time, future studies could benefit from analyzing larger datasets spanning multiple years. Such longitudinal studies would help confirm the enduring impact of foreign and national female players on team performance, offering invaluable guidance to coaches in their recruitment processes. This study has advanced

our understanding of the dynamics in female basketball player performance, these outlined limitations highlight the need for continued research in this domain. By addressing these limitations and exploring new avenues, future studies can further enrich our insights into the contributions of national and foreign players in elite female basketball.

(2) This segment, like any research endeavour, is not without its limitations, and it is important to acknowledge these constraints in the context of future research. Firstly, the inability to implement objective monitoring of menstrual phases, such as through hormonal sampling, represents a limitation. Employing hormonal data would have offered a more precise and accurate understanding of the players' menstrual cycles (Julian et al., 2021). This addition would have enriched the study and provided more comprehensive insights into the relationships between menstrual phases and player performance.

Secondly, the data collection was confined to a specific 14-week timeframe, corresponding to the regular season phase. Consequently, the findings derived from this study are specifically relevant to this season phase, and their applicability to other phases, such as pre-season or playoffs, remains unexamined. Future research should consider encompassing these distinct phases to provide a more comprehensive understanding of how menstrual phases impact performance across the entire basketball season (Sansone et al., 2021).

A third limitation pertains to the focus on monitoring a single team, essentially treating it as a case study. While this approach allows for an in-depth exploration of a specific team, it restricts the generalizability of the findings to a broader population of teams and players. Future research should endeavour to encompass multiple teams to capture a more diverse range of experiences and performance outcomes. The constraints imposed by logistical and financial factors primarily influenced these aspects and underscore the need for larger, more comprehensive studies to address these limitations.

(3) Certainly, let's expand upon each of the study's limitations:

(i) The study's first limitation pertains to its exclusive focus on European basketball competitions, characterized by relatively shorter travel distances when compared to their American counterparts. While this allowed for a more manageable scope, it does raise questions about the generalizability of the findings to a broader, more geographically diverse context. It would be prudent for future research to incorporate a wider range of basketball competitions, including those in the United States, to better understand how varying travel distances impact player performance.

(ii) Another notable limitation is that the study concentrated solely on the EuroLeague, renowned for featuring the best basketball teams and clubs in Europe. The top-tier status of this league is associated with superior organizational standards, high-quality hotels, and optimal dietary provisions for players. It is important to acknowledge that these favorable conditions may not be representative of leagues at medium or lower competitive levels, where organizational standards, accommodation, and nutrition may vary. This disparity between the EuroLeague and other leagues needs to be considered when assessing the transferability of the study's results. Future research could benefit from including leagues of diverse competitiveness to account for these variations.

(iii) An additional limitation arises from the absence of data regarding the potential need for some players to undertake extra travel, such as driving back home or using alternative modes of transportation. This unaccounted variable could introduce an additional physical and mental load on the players. Future research endeavors should aim to gather data on such factors, as it could play a significant role in shaping the overall impact of travel on player performance.

(iv) The study's fourth limitation relates to the lack of information regarding players' training loads during the week and the periods between games. Understanding how training intensities and workloads vary within the context of the congested fixture schedule is essential to provide a comprehensive analysis of player performance. Integrating this data into future research would offer a more holistic perspective on how training regimens interact with game-related statistics.

(v) Finally, there are several unmeasured variables that may influence the study's outcomes, including the geographical location of home team stadiums, the altitude of these locations, the population size of the cities, and the use of medical recovery instruments. These variables have the potential to introduce unique factors that could affect player performance in diverse ways. Further research should consider these variables as potential factors that may contribute to variations in game-related statistics and overall player performance.

4.3 Future Directions

(1) In light of the insights gleaned from our research, it is recommended that future studies delve deeper into the exploration of both independent and interactive effects of an array of contextual factors. These factors could encompass the match's status, the specific game period, the type of competition in which the players are engaged, and the degree of fixture congestion within the schedule. By scrutinizing these factors in relation to both national and foreign players, researchers can unlock a richer understanding of the complex dynamics at play within basketball teams. Furthermore, it is advisable to extend this investigation to encompass the analysis of how these factors influence individual and collective playing styles, ultimately shaping team performance.

This avenue of research has the potential to bridge the theoretical insights derived from

academic inquiry with practical applications within the realm of basketball. By delving into the nuanced interactions between various factors and their effects on player and team dynamics, future studies can contribute to a more comprehensive and practical understanding of the sport. This will not only benefit the academic community but also offer valuable insights to coaches, athletes, and basketball professionals, allowing them to make more informed decisions and optimize strategies based on the contextual realities of the game.

(2) Considering the outcomes of this study, it is evident that there is a promising path for future research to further explore the interplay of the menstrual cycle, physical variables, and GRS in the context of female basketball competition. One avenue for enhancing the robustness of findings is through the expansion of data samples by incorporating a longitudinal analysis. This approach offers the advantage of tracking changes and patterns over time, ultimately increasing the accuracy and validity of the results.

Furthermore, to achieve a more comprehensive understanding of the subject matter, it would be beneficial to include a diverse range of player performance levels in the research. This can involve studying athletes from different tiers or skill levels within the realm of basketball. By doing so, researchers can gain a multi-dimensional insight into the specific match demands experienced by individuals. This broader perspective will provide a more holistic understanding of the complex dynamics at play during games.

Future research in this domain holds the potential to offer valuable insights into the influence of the menstrual cycle and physical factors on female basketball performance. By expanding data samples and encompassing a diverse range of player profiles, the research can evolve to provide a more nuanced and comprehensive perspective on the subject, ultimately benefiting players, coaches, and the basketball community at large.

(3) Future research endeavors should delve more deeply into the realm of team performance across different levels or divisions. This exploration will allow for a more comprehensive understanding of the intricacies involved in the dynamics of various basketball teams, shedding light on the unique challenges and factors that shape their performance.

Additionally, it would be worthwhile for upcoming studies to actively seek solutions to address the limitations encountered in our research. By doing so, researchers can pave the way for more precise and detailed information regarding the performance of specific players at different levels. This proactive approach will contribute to a more accurate and well-rounded knowledge base, benefiting both the scientific community and those involved in the world of basketball.

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CHAPTER 5

Overall conclusion

Chapter 5 Overall Conclusion

5.1 Overall Conclusion

In order to present the final conclusions of this PhD Thesis, these ones were split according to each aim/ section:

Aim 1: The discriminative power of game-related statistics has produced valuable insights into the distinctive performances of national and foreign players, considering team ability and playing position. Our findings shed light on several key performance indicators where foreign players demonstrated notable advantages:

1. **Playing Time:** Foreign players consistently experienced more time on the court compared to their national counterparts, highlighting their crucial role in team strategies.
2. **Shooting Proficiency:** Foreign players exhibited superior shooting skills in terms of successful free-throws and 2-point field-goals across various playing positions, showcasing their scoring prowess.
3. **Teamwork:** Notably, foreign Guards and Forwards excelled in teamwork, particularly in terms of assists, underscoring their ability to facilitate collaborative actions on the court.
4. **Rebounding:** In the case of Guards, foreign players displayed stronger defensive capabilities, while Centres were more effective at securing offensive rebounds, emphasizing their roles in different aspects of the game.
5. **Turnovers:** Forwards from foreign backgrounds had a higher rate of turnovers, indicating a potential area of risk in their game.

Aim 2: Regarding the Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors, the main objective of this study was to assess the influence of various factors on game-related statistics in professional female basketball players. These factors encompassed the physical and perceptual demands of the game, perceived recovery, menstrual cycle phase, individual player characteristics, and game-related contextual factors. The key findings from this investigation were as follows:

1. Player Load per minute ($PL \cdot \text{min}^{-1}$) had no significant impact on any of the key performance indicators.
2. Higher Ratings of Perceived Exertion (RPE) scores were associated with improved overall performance (PIR) and shooting performance (eFG%).
3. Players in the follicular phase of the menstrual cycle exhibited better effective field goal percentage (eFG%) and a higher number of rebounds.
4. Reporting a higher level of recovery before the game resulted in improved shooting performance (eFG%).
5. The intricate interactions among various factors, including individual characteristics, game context, recovery status, menstrual phase, and perceived game demands, had multiple effects on Player Impact Rating (PIR) and effective field goal percentage (eFG%). These findings underscore the importance of considering these diverse variables in concert to optimize player performance.

Aim 3: The study investigating the impact of varying weekly game loads on the performance of top European female basketball players throughout a full season of European competition

has unveiled several noteworthy findings:

1. **Non-Linear Relationship Between Rest and Performance.** The research revealed a non-linear relationship between rest and team performance. Initially, rest positively influences performance, but this effect plateaus and diminishes as the duration of rest increases. In other words, there is an optimal level of rest beyond which performance gains become less pronounced.

2. **Player Adaptation to Congested Schedules.** It appears that players may have adapted to the demands of a congested schedule. Extended rest periods can disrupt their physical rhythms, leading to potential repercussions on their overall game performance. This suggests that too much rest might not be beneficial for their performance due to an adjustment to the fast-paced schedule.

3. **Impact of Home Advantage.** Interestingly, when the home team plays a game with zero rest days, the expected points scored by the home team receive little to no advantage from the traditional home-court advantage. This implies that the well-documented benefits of playing at home may not apply in scenarios of back-to-back games, highlighting the unique dynamics at play in such situations.

In summary, this study offers valuable insights into how game load and rest duration affect the performance of top European female basketball players during a full season of competition, shedding light on the complex relationship between rest, adaptation to schedules, and the impact of home advantage in the world of professional basketball.

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CHAPTER 6

Practical application

Chapter 6 Practical application

6.1 Practical application

The findings of the PhD thesis yield several practical applications, offering recommendations for enhancing the quality of training, match analysis, and game comprehension.

Firstly, these findings hold significant implications for team managers and coaches in the recruitment and training processes for elite female basketball teams. Managers can use this information to make more informed decisions when selecting national and foreign athletes to build successful rosters. Moreover, coaches can tailor their technical-tactical training sessions to address specific vulnerabilities identified through these performance disparities, ultimately enhancing player performance during competition. This deeper understanding of player dynamics within the sport can contribute to the continued growth and success of elite female basketball teams.

Secondly, to begin, our study revealed several noteworthy findings. We observed that a general physical intensity indicator, exemplified by $PL \cdot \min^{-1}$, did not exert any discernible influence on players' technical performances. It became evident that assessing physical demands necessitates a more detailed contextualization, accounting for various factors like game phases, the scoreline, or tactical constraints.

We recognized that the interpretation of game RPE should be nuanced, considering individual playing times and game outcomes, as these factors may introduce confounding variables into the equation. Therefore, the assessment of game RPE should incorporate these critical nuances.

Moreover, our results strongly suggest that basketball practitioners should take menstrual cycle phases into consideration when evaluating their effects on key performance indicators. Notably, female players displayed enhanced shooting (eFG%) and rebounding (REB) performances during the follicular phase. Coaches, equipped with this knowledge, could strategically adapt their game plans. For instance, they might choose specific set plays to capitalize on increased shooting abilities during the follicular phase, creating more opportunities for success. Similarly, they could tailor tactical roles to align with rebounding strengths during this phase, increasing the likelihood of securing rebounds and, consequently, elevating the team's performance. Furthermore, our findings indicate that better shooting performances can be expected from players who report improved recovery (TQRpre). This suggests that coaches might consider last-minute modifications to their game tactics based on TQRpre scores, optimizing their strategic approach.

The intricate interactions between various factors, including physical, physiological, perceptual, hormonal, individual, and technical-tactical elements, underscore the multifactorial nature of basketball performance. Coaches and their staff should remain acutely aware of these complex interactions, recognizing that a holistic understanding is essential for optimizing player and team performance on the basketball court.

Thirdly, Having information about the advantages and disadvantages presented by the schedule, including details like previous matches and whether the games are played at home or away, empowers the staff to make crucial decisions regarding on-field strategies, training plans, and the specific game approach to be employed during matches.

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PhD Thesis

D. Lorenzo Gasperi

Appendix

Appendix

PhD candidate's publications and Conference Presentations

Publications in scientific journals

Gasperi, L., Conte, D., Leicht, A., & Gómez-Ruano, M. Á. (2020). Game related statistics discriminate national and foreign players according to playing position and team ability in the women's basketball euroleague. *International journal of environmental research and public health*, 17(15), 5507. **(Published)**

Gasperi, L., Sansone, P., Lukonaitiene, I., A., & Gómez-Ruano, M. Á., Conte, D. (2023). Female basketball game performance is influenced by menstrual cycle phase, age, perceived demands and game-related contextual factors. *Journal of sports sciences*. DOI:10.1080/02640414.2023.2285119
(Published)

Presentations in International Conferences

Gasperi, L. & Gómez-Ruano, M. Á. (2020). Can the different weekly game load influence the performance in top European female basketball players?. The 2nd Belt and Road Physical Education and Sport Forum **(Mini Oral)**