applied sciences

MDPI

Article

Kinematic and Neuromuscular Ranges of External Loading in Professional Basketball Players during Competition

Sergio José Ibáñez [1,*], Pablo López-Sierra [1], Alberto Lorenzo [2] and Sebastián Feu [1]

1 Research Group in Optimization of Training and Sports Performance (GOERD), Faculty of Sport Science, Department of Didáctica de la Expresión Musical, Plástica y Corporal, University of Extremadura, 10003 Cáceres, Spain; plopezp@alumnos.unex.es (P.L.-S.); sfeu@unex.es (S.F.)
2 Faculty of Sciences for Physical Activity and Sport, Polytechnic University, 28040 Madrid, Spain; alberto.lorenzo@upm.es
* Correspondence: sibanez@unex.es

Abstract: Personalization of workloads is essential for optimizing training processes and minimizing the risk of injuries in sports. Precise knowledge of the external load demands borne by basketball players during competition is necessary for this purpose. The objective of this research was to determine the objective external load demands of five variables during a basketball competition, three kinematic (speed, accelerations, and decelerations) and two neuromuscular variables (impacts/min and Player Load/min), and subsequently establish workload ranges. Six official matches from preparatory tournaments involving professional basketball players from the Spanish first division, Liga ACB, were analyzed. Inertial devices and an UWB system were used for variable localization and recording within indoor spaces. Two methods, two-step and k-means clustering, were employed for workload range classification. The results revealed different workload thresholds clusters based on the data analysis technique used. The following speed ranges were identified in professional basketball players: Standing, <2.95 km/h; Walking, 2.96 to 7.58 km/h; Jogging, 7.59 to 12.71 km/h; Running, 12.72 to 17.50 km/h; and Sprinting, >17.51 km/h. The center of cluster 5 was found to determine the concept of a sprint (>19 km/h) as well as high-speed running (>17.50 km/h). Acceleration and deceleration ranges displayed few cases but with considerably high values, which must be considered when designing injury prevention tasks. The distribution of impacts showed a normal pattern, with identified periods during which players withstood significant G-forces (14%). Finally, the Player Load value at which an activity is considered to be very high, 1.95 au/min, was identified. Considering the obtained results, basketball is proposed as a sport with a high neuromuscular load. Coaches should choose the classification method that best suits their needs. These reference values are the first of their kind for this population of top-level professional players and should aid in adjusting training processes to match competition demands.

Keywords: inertial devices; personalization; external load; competition; male

Citation: Ibáñez, S.J.; López-Sierra, P.; Lorenzo, A.; Feu, S. Kinematic and Neuromuscular Ranges of External Loading in Professional Basketball Players during Competition. *Appl. Sci.* **2023**, *13*, 11936. https://doi.org/10.3390/app132111936

Academic Editors: Jacek Polechoński and Piotr Wodarski

Received: 9 October 2023
Revised: 24 October 2023
Accepted: 27 October 2023
Published: 31 October 2023

1. Introduction

Basketball is a physically demanding sport that involves high-intensity movements such as jumps, cuts, sprints, quick direction changes, and defensive maneuvers [1,2]. These repeated actions over time can lead to overuse injuries, such as stress fractures, tendinitis, and muscle strains, if not adequately controlled in players [3,4]. Load monitoring in basketball allows for understanding and manipulating factors such as training volume, intensity, and recovery to optimize performance and minimize the risk of injuries and fatigue [5,6]. Gabbett and Domrow [7] highlighted that excessive training load and inadequate recovery can increase the risk of injuries in basketball players. To mitigate these effects, it is necessary to implement proper load monitoring by scientifically establishing the ranges of internal and external load to which players will be exposed during training processes [8].

Load monitoring helps personalize training programs to satisfy the specific needs of each player. Not all players have the same physical and physiological capacities, injury history, or recovery ability, as well as varying levels of skill and athletic capacity. Furthermore, the load is conditioned by the functions and actions performed by players based on their specific positions [9,10]. By controlling and adjusting the load according to individual characteristics, coaches can ensure that each player's training is appropriate for their level and help them reach their full potential.

The personalization of load should be based on knowledge of the demands imposed by competition [11–13]. Reina et al. [14] stated that the personalization of external and internal load thresholds allows for tailoring training to the specific characteristics of each player, optimizing physiological adaptation, and enhancing individual performance by adjusting training volume and intensity according to their specific needs, thereby improving physical performance [15,16] and technical-tactical skills [17,18]. The mechanical and locomotor stress endured by athletes during training or competition is considered as the external load [19], which can be measured through kinematic variables (speeds, accelerations, decelerations, distances, etc.) that allow us to know the work ranges, or through neuromuscular variables (impacts, Player Load, Power Metabolic) that allow us to identify the accumulated load.

In the case of basketball, it is known that several methodological factors (such as the instrument used to measure, the study design including or not warm-ups, or game breaks), and external factors (such as playing position, gender, competition level, or age category) condition the training and competition load [20–22]. Therefore, samples should be individualized and specified according to the factors mentioned above to obtain a better understanding of data collection.

For the monitoring of internal and external load, there are different subjective and objective methods which coaches use depending on their knowledge and availability of economic resources. Among the subjective methods for internal load control, the most commonly used is the Rating of Perceived Exertion (RPE) method [23], while for external load it is the Integral System for Task Analysis (SIATE) [24]. The use of objective methods requires equipment that sometimes has a high cost, limiting its use by some coaches. For internal load monitoring, heart rate bands are used to obtain different metrics on heart rate or to calculate load values such as Banister's TRIMPs [23]. The use of state-of-the-art inertial devices, IMUs, based on the recording of the athlete's positioning and accelerometry monitoring [25] is the most widely used method at present. These devices allow obtaining multiple objective external load variables of kinematic, neuromuscular, and tactical nature via their ability to record the movements of the athletes through the field of play and the interaction between them [26]. In indoor sports, in recent decades, Local Positioning Systems, LPS, are being applied for monitoring players during training and competition. The technology associated with LPS for data collection (ultra-wideband radio frequency) involves the placement of signal emission-reception systems that, in sports facilities where matches are played, are not allowed by federations and institutions during official matches, as well as the use of inertial devices on the body of athletes. Therefore, there is a lack of reference values derived from LPS in high-level competitive players and in competition. It is necessary to know the thresholds of the objective external load variables that occur during official competition with professional basketball players, as this will allow the development of more precise conditioning programs adjusted to this population.

The highest quality IMUs on the market have specific software for processing the raw data obtained during monitored sports practice. By default, these software packages establish a series of reference values to identify actions or ranges of movement. Thus, almost all of them establish that the concept of sprinting is performed when an athlete moves at more than 24 km/h. From this value, speed ranges are established. The five speed ranges defined in the SPro software of the company RealTrack Systems (Almeria, Spain) are as follows: Very Low/Standing, Low/Walking, Moderate/Jogging, High/Running, and Very High/Sprinting. However, it is necessary to have a critical position with respect to these proposed intervals (which come from the analysis of the activity of soccer players), and to analyze if they are really applicable to other sports specialties and other populations.

Monitoring of basketball teams has identified that the players have been running at their maximum intensity during training and competition. The speeds reached are conditioned by the dimensions of the playing field (28 × 15 m in FIBA basketball), and it is very difficult to reach the reference values presented in the literature. The establishment of the reference thresholds should be carried out taking into account the maximum demands made by the players during competition, the gender of the athletes, and the competitive level, generating specific thresholds for each population of athletes. In order to carry out comparative studies between different sports modalities, it will be important to take into account both the absolute value (maximum) and the relative value (specific ranges).

Researchers have begun to customize these thresholds to the populations under study. To do so, they record the actions they want to analyze, and, based on them, with the raw data provided by the IMUs, they make the corresponding clusters according to the values obtained. In school populations, studies are found that propose the following thresholds within physical education classes for teaching basketball [27] or soccer [28]: walking ≤ 6 km/h, jogging 6–12 km/h, running 12–18 km/h, and sprinting ≥ 18 km/h. For their part, Gamero et al. [29] again adapted these ranges to their school context and group of students by reducing the values as follows: walking ≤ 5.2 km/h, jogging 5.2–10.5 km/h, running 10.5–15.7 km/h, and sprinting ≥ 15.7 km/h.

This adaptation has also been made in studies on the sport of basketball. The literature contains proposals for speed ranges according to the sex of the players, as well as age and competitive level (Table 1). These ranges differ fundamentally according to the methodology used for the classification, the gender, the sport level of the sample, and the IMUs used. Some researchers obtained the data during collective game situations, five vs. five, during training, in simulated game situations, or during competition. These reference values can serve coaches to adjust the design of training tasks to the real demands of competition.

Table 1. Studies using speed ranges in basketball.

Author	Sex	Level	Standing km/h	Walking km/h	Jogging km/h	Running km/h	Sprinting km/h
Reina et al. [30]	Female	U'18	≤3.6	3.6–6.5	6.5–10.2	6.5–10.2	>14.4
Vázquez-Guerrero et al. [31]	Male	U'18	≤6.0	6.0–12.0	12.1–18.0	18.1–24.0	>24.1
Sosa et al. [32]	Male	U'18		<7.0	7.0–14.0	14.0–18.0	≥18.0
Puente et al. [33]	Male	Senior non-professional	≤6.0	6.1–12.0	12.1–18.0	18.1–24.0	≥24.0
Ibáñez et al. [8]	Female	Senior Professional and semi-professional	≤2.31	2.31–5.33	5.34–9.32	9.33–13.12	13.13–17.08
Scanlan et al. [6] *	Male	Senior Professional and semi-professional		≤3.6	3.96–10.8	11.16–25.2	>25.2

* Values converted from m/s to km/h.

In addition to these studies that identify ranges for the kinematic variable of speed, in the literature, there are other studies that establish ranges for distances traveled [34], accelerations and decelerations [8], impacts [8], or Player Load [35], which show reference values for individualization of training and adaptation to the demands of competition.

In the evolution of basketball research, ref. [36] presented a relationship between the four phases through which data analysis in sport evolves proposed by Houtmeyers et al. [37] (Descriptive analysis, Diagnostic analysis, Predictive analysis and Prescriptive analysis) with the techniques for data analysis. Clustering techniques would be found within the Diagnostic phase, whose objective is to establish the performance profiles of athletes. Within the clustering techniques, two of the methods that are commonly used for the grouping of cases are two-step clustering and k-means clustering. These two techniques provide very relevant information but differ in their approach and underlying principles. Two-step clustering involves a hierarchical process consisting of two stages. The first stage involves grouping the data using a less complex clustering algorithm (cluster analysis), followed by a more refined clustering analysis (logistic regression analysis). Two-step clustering is based on a combination of distance and probability measures. K-means clustering is one of the most popular and widely used methods in cluster analysis. This algorithm seeks to group objects into k clusters, where k is a predetermined number [38].

The results obtained with two-step clustering offer more robust results, as its approach is based on logistic regression and distance measures, whereas k-means clustering is based on minimizing the sum of squared distances within each cluster. The number of clusters in two-step clustering is not set in advance and is determined optimally during logistic regression, whereas in k-means clustering, the number of k clusters is set in advance by the researcher. The use of these clustering techniques will depend on the objective of the study. Although two-step clustering may be a better model, sometimes the clusters it proposes may not discriminate sufficiently for the work of the trainers. Therefore, it is necessary to experiment with the different solutions provided by each model.

As far as is known, there are few studies that define the work ranges in objective external load (OEL) variables in professional basketball players during official competition. Likewise, there is very little research that, based on a mathematical model, establishes the ranges, as well as confronts different models to better define these ranges. This type of information is necessary for coaches to be able to adapt training processes to the real demands of competition. Therefore, the general objective of this research was to determine the objective external load demands during the basketball competition of five variables, three kinematic (speed, accelerations, and decelerations) and two neuromuscular (impacts and Player Load), and subsequently establish workload ranges. In addition, a complementary objective was established to analyze the results of the clusters according to the mathematical model used in order to identify the best criteria for classification.

2. Materials and Methods

2.1. Design

This research is classified as a non-experimental design, as no variables are manipulated and no treatment is assigned [39]. Specifically, this study is empirical with a quantitative methodology, with a descriptive strategy, natural, as the research takes place in the usual context in which the phenomenon occurs, and cross-sectional, as the players' data are recorded at a single, specific moment: the competition [40].

2.2. Participants

The participants of this research were six of the teams that played two official preseason tournaments during the 2022–2023 season. The records were obtained from six games and six teams of the first professional basketball league in Spain, the ACB League.

A total of 68 players who met the previously defined inclusion criteria participated in this research. The inclusion criteria were the following: (a) belonging to the official squad of the first team of the ACB League; (b) playing at least 5 min of the tournament; (c) not having suffered a musculoskeletal injury in the 15 days prior to the game, which limits their maximum performance during the game; (d) having had an adaptation period of 10 days prior to the technological equipment that will be equipped during the competition and accepting to have it equipped during the games; (e) participating voluntarily and signing an informed consent form.

The managers of each team were informed of the purpose of the research, as well as the potential risks and benefits, and their consent was received. The players and coaches were subsequently informed about the procedure to be followed in the research and the possible risks and benefits of participation. The coaching staff and the basketball players of each team decided to participate in this research on a voluntary basis by signing an informed consent form. The research was guided by the ethical principles and procedures set out in the Declaration of Helsinki (2013) and was approved by the University Bioethics Committee (233/2019).

2.3. Sample

The sample was obtained from the records of six official games of teams from the first professional basketball league in Spain, the ACB league. These matches were played during the pre-season period during the 2022–2023 season. Because the league's organizational rules do not allow the use of inertial devices during official competition, these records were obtained during two official pre-season tournaments.

The sample was composed of the records of the players who participated in the analyzed matches and who satisfied the inclusion requirements. Data collection was carried out with inertial devices with a sampling frequency of 100 Hz. A total of 3,345,703 cases were obtained for the speed variable, 22,943,386 cases for the acceleration variable, 26,451,233 cases for the deceleration variable, and 257 cases for the impacts and Player Load variables.

2.4. Variables

Five variables belonging to two types of objective external load (OEL) variables were analyzed in this study: on the one hand, the kinematic OEL variables speed, accelerations, and decelerations (variables with which a continuum of data per second can be obtained with inertial devices, being the most accurate measurement that can be obtained to perform an analysis), and, on the other hand, the neuromuscular OEL variables impacts/min and Player Load/min (cumulative variables of the load supported by the player). The latter variables were obtained from the individual periods of continuous play of each player, weighted to the playing time measured in minutes. Table 2 describes the study variables.

Table 2. External load variables used in the study.

Variable	Unit	Description
Speed	km/h	Space traveled in a unit of time
Accelerations	m/s^2	Positive speed variation
Decelerations	m/s^2	Negative speed variation
Impacts/min	Number of G-force impacts/min	Sum of impacts measured in G-forces supported by the athlete in the three planes per minute.
Player Load/min	arbitrary unit/min	Cumulative load resulting from acceleration in the 3 axes per minute

The values of the speed and acceleration variables collected in the study do not have any cut-off threshold. For each player, the continuum of data was extracted throughout the entire match. In this way, for every millisecond, the evolution of all the values of the kinematic variables is obtained, providing very precise values when it comes to knowing the movements of each player at each moment. Therefore, all values between the value 0 and the maximum value reached during the match are included. The data were obtained from of the total time the player was on the court. That is, from the time he enters the court until he is substituted by the coach or the period of play ends. This time includes the natural pauses in the game (throw-ins, personal fouls, free throws, time-outs, etc.). The times when the player is on the bench were excluded from the study.

2.5. Equipment

To obtain the data, all the players were equipped with inertial devices model Wimu Pro™ (RealTrack Systems, Almería, Spain), which were fitted in an anatomical harness to be placed on the player's back, at the intra-scapular level between T2 and T4. These IMUs are prepared for recording indoors as they are equipped with ultra-wideband technology, UWB, at a frequency of 33 Hz. The UWB system used consists of eight antennas that transmit the signal to locate the devices. Their placement on the field of play allowed the competition to take place without disturbing the intervention of the referees and players. Two antennas were placed on each side of the field following the manufacturer's instructions (Figure 1). The recommendations proposed by Pino-Ortega et al. [41] for switching on and calibrating the equipment were followed in order to guarantee the reliability and validity of the measurements.

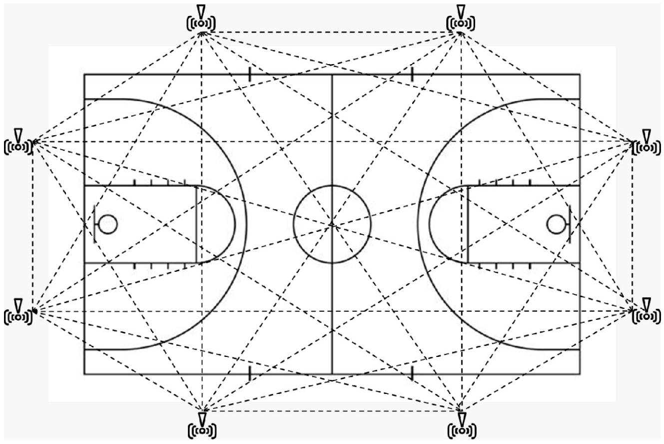


Figure 1. Location of UWB antennas on the playing field.

2.6. Procedures

This research was carried out in four phases. In the first phase, the clubs were contacted to inform them of the objective of the research, as well as the benefits and possible risks for the athletes. After the consent of the clubs, the organizations of the tournaments in which the clubs participated were contacted, in addition to informing them of the objectives of the research, to request authorization for the placement of the UWB equipment on the playing fields. Once the proposal was accepted, the coaches and players of the participating clubs signed the informed consent form.

In the second phase, data were obtained from the six official games played in these two tournaments. To collect the data, all the players were equipped with an anatomical harness in which the inertial device was inserted, as well as a heart rate band. In order not to alter the players' preparation before the match, the equipment was placed on them on their arrival at the pavilion. The placement and calibration of the UWB antennas was performed 90 min before the start of the match, so as not to interfere with the preparation of the teams.

The third phase corresponds to data collection and extraction. Once the matches were over, the data were extracted from the inertial devices to the specific software for this equipment, SPro™. Once the corresponding analyses had been carried out to select the time sequences in which the players were intervening during the matches, the raw data were exported to the SPSS 25 data analysis program to carry out the cluster analyses. Raw data were imported into the statistical package for the UWB speed channels (km/h) and the acceleration and deceleration values (m/s^2) of each positive and negative speed change generated by all players during the matches. One file was generated for each variable under study with all the data of the players. This file was used to perform the cluster analysis.

In the final phase, the data were analyzed, and the results grouped using two different methodologies: on the one hand, an unconditional analysis using two-step clustering, and on the other hand, using the five-group k-means clustering algorithm, as has been the usual practice in the literature to date.

2.7. Statistical Analysis

With each of the five variables selected in this study, two cluster analyses were performed: two-step clustering to identify the load zones automatically, and five-rank K-means clustering as previous research has employed [8,30,31]. These investigations have employed expert judgment to establish load thresholds. The researchers believe that with these five levels, the demands of the players for each of the variables can be better discriminated. After identifying the centers of each cluster, a new variable identifying the membership of each case was generated to identify the lower and upper values and thus determine the working areas of each variable. The one-way ANOVA was used to confirm that the groups generated were different and mutually exclusive.

The results obtained were presented in tables, including, for each of the five variables, the cluster centers, the ranges of each zone, the number of cases or percentage of cases, as well as a graph with the distribution of cases, to visually appreciate the weight of each group within the set.

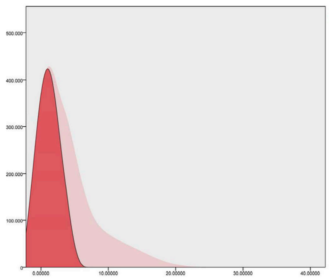
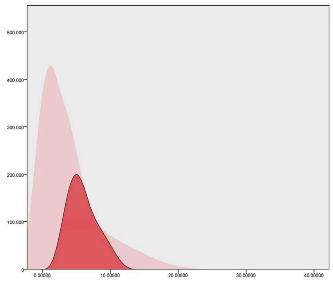
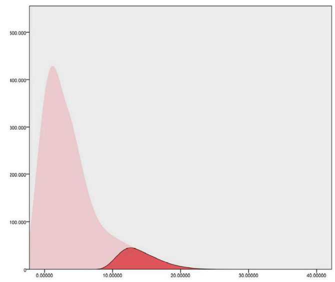
Data analysis was performed using the Statistical Package for the Social Sciences (SPSS, IBM, SPSS Statistics, v.25.0, Armonk, NY, USA).

3. Results

3.1. Speed Cluster

Table 3 shows the results of the two-step cluster to group the speed ranges in an unconditional way. The values of the cluster center, the speed ranges included in each group, and the percentage of cases included, as well as their visual distribution, are presented. Three speed groups are identified: Low/Walking; Moderate/Jogging; Very High/Sprinting. Men's professional basketball is a sport in which the speed during a game is very low, less than 3.5 km/h, almost 60% of the time, with periods of moderate speed (30%) and high-speed peaks (10%).

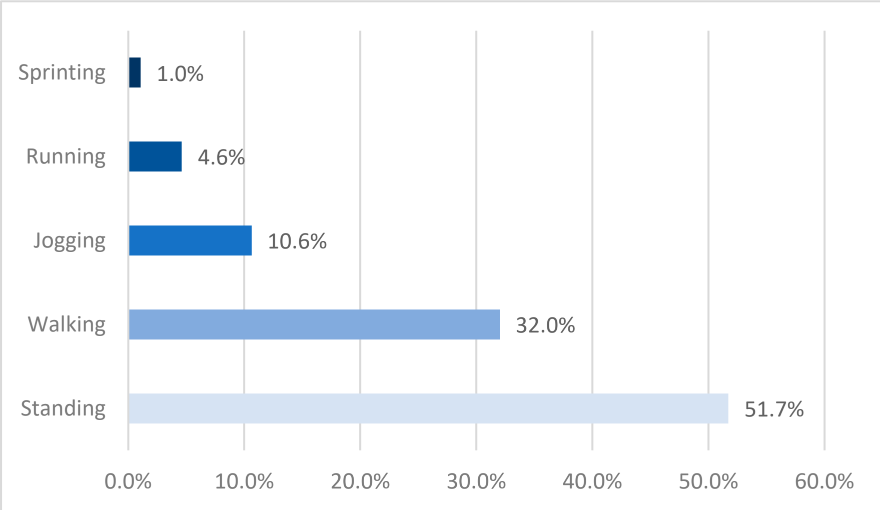
Table 3. Results of the two-step cluster of kinematic OEL speed.

Speed (km/h)	Low/Walking	Moderate/Jogging	Very High/Sprinting
Cluster centers	1.17	5.94	14.06
Ranges	<3.51	3.52 to 10.62	>10.63
%	57.9%	33.0%	9.1%
Distribution			

Although this information is very valuable for coaches, it does not discriminate the work that they can plan for the improvement of their players. This type of classification does not allow identifying the referential values that allow programming a sprint or a high-intensity effort in the applications that the inertial devices provide. Therefore, a K-means cluster of five groups was performed following the usual classifications in the literature: Very Low/Standing; Low/Walking; Moderate/Jogging; High/Running; Very High/Sprinting. The results are presented in Table 4.

The K-means cluster analysis identified five speed groups different from each other (F = 10027814.10; gl 4; $p < 0.001$), with significant differences between the groups. Again, it is identified that the basketball player spends more than 80% of the time standing or walking, while only 1% of the time moving at high intensity. The value of the center of the Very High/Sprinting cluster can be considered as the value from which it can be thought that professional basketball players perform a sprint, at a speed above 19 km/h. These results also allow us to configure and identify HSRs, which are produced at more than 17.5 km/h. This information allows us to configure the specific software of these IMUs, the SPROTM, to classify the speeds in the specific ranges of this population.

Table 4. Results of the five-k means cluster of kinematic OEL speed.

Speed (km/h)	Very Low/Standing	Low/Walking	Moderate/Jogging	High/Running	Very High/Sprinting
Cluster centers	0.92	4.73	9.85	14.70	19.35
Ranges	<2.95	2.96 to 7.58	7.59 to 12.71	12.72 to 17.50	>17.51
n	1,730,473	1,071,090	355,007	154,115	35,018
Distribution					

3.2. Acceleration and Deceleration Clusters

Table 5 presents the results of the non-predefined cluster of accelerations and decelerations. Three ranges of accelerations and two of decelerations are identified. There is a greater number of decelerations than accelerations, meaning that changes in speed under -2m/s^2 are more frequent. Accelerations occur more progressively, while decelerations happen more abruptly. The number of high-intensity accelerations is scarce. Generally, decelerations progress gradually, with 30% of them being moderate but with high ranges. Decelerations, while braking, are highly intense, so this factor must be considered by trainers to strengthen the muscle groups responsible for braking and thus prevent potential injuries.

Table 5. Results of the two-step cluster of OEL kinematics accelerations and decelerations.

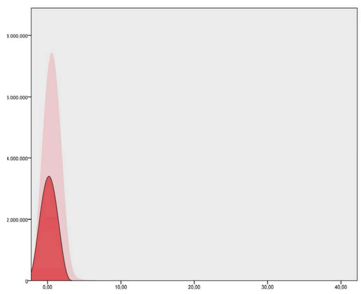
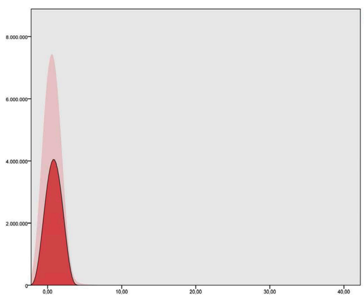
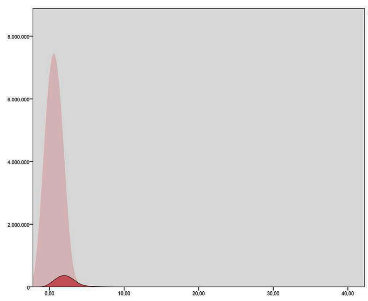
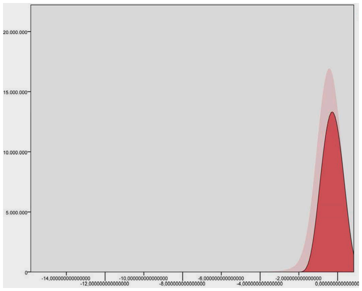
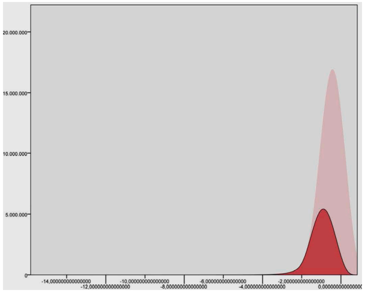
ACCELERATIONS			
Acc (m/s^2)	Low	Moderate	Very High
Centers	0.19	0.82	2.16
Ranges	<0.45	0.49 to 1.42	>1.43
%	43.1%	51.7%	5.2%
Distribution			

Table 5. *Cont.*

DECELERATIONS		
Dec (m/s²)	**Low**	**Moderate**
Centers Ranges %	−0.28 −0.62 to 0.0 69.5%	−0.97 −14.55 to −0.63 30.5%
Distribution		

The unconditioned cluster does not provide an accurate discrimination of acceleration and deceleration ranges. Therefore, Table 6 presents the results of a classification of these two variables into five ranges. The K-means cluster analysis identifies five distinct groups of accelerations (F = 10460669.16; df 4; $p < 0.001$) and decelerations (F = 28248438.51; df 4; $p < 0.001$) with significant differences between each of the five groups.

With this clustering, it is confirmed that most accelerations occur at very low intensity, meaning that players progressively increase their speed. Speed increments are smaller when the player is already moving at high intensity. These speed changes might be the factors that differentiate one player from another.

Table 6. Cluster results of five kinematic OEL ranges for accelerations and decelerations.

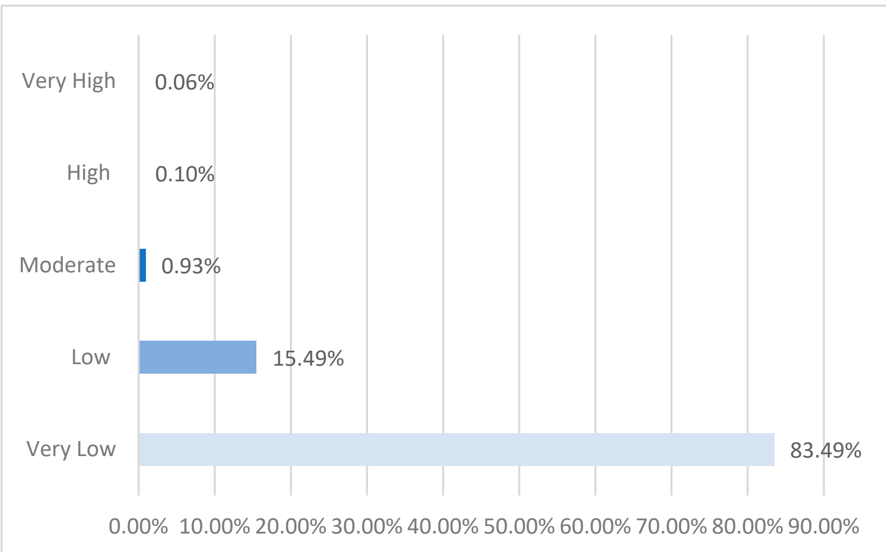
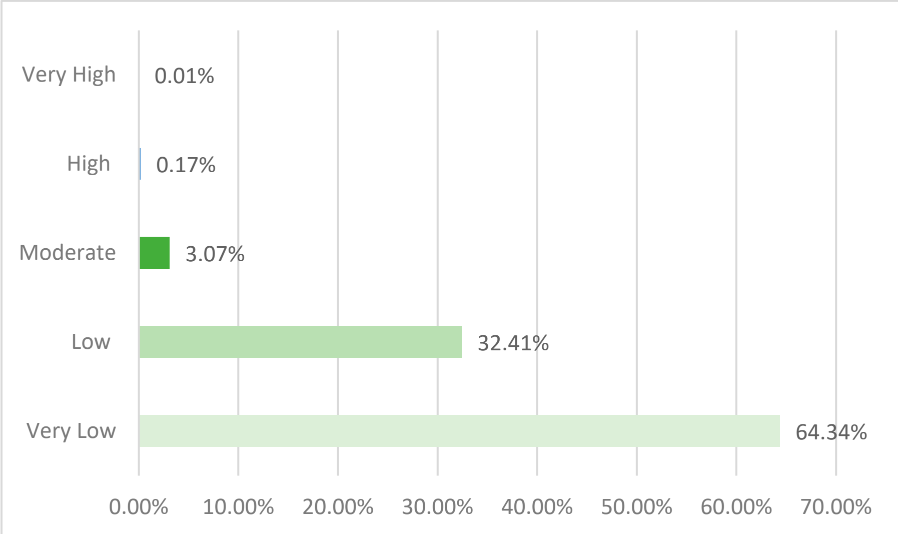
ACCELERATIONS					
Acc (m/s²)	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Centers (m/s²) Ranges (m/s²) *n*	0.46 <0.95 19,155,209	1.29 0.96 to 2.53 3,553,364	3.34 2.54 to 5.31 212,237	6.49 5.32 to 12.25 22,456	14.23 >12.26 120
Distribution					

Table 6. *Cont.*

DECELERATIONS					
Dec (m/s^2)	**Very Low**	**Low**	**Moderate**	**High**	**Very High**
Centers (m/s^2)	−0.26	−0.82	−1.78	−3.72	−7.91
Ranges (m/s^2)	−0.56 to 0.0	−1.37 to −0.57	−2.98 to −1.38	−6.27 to −2.99	−14.55 to −6.28
n	17,019,957	8,571,962	812,185	45,195	1934
Distribution					

Regarding the decelerations grouped into five categories, it is observed that over 90% of the decelerations are of low intensity, less than 2 m/s^2. Perhaps the most relevant finding in this cluster is the verification that there are reductions in speed, braking, of moderate, high, and very high intensity, necessitating the design of tasks that can replicate these sudden speed reductions.

It is essential to remember that the sampling frequency is 100 Hz, so speed variations in both positive and negative directions are recorded 100 times per second. Therefore, the magnitudes of accelerations in the Very High range correspond to a positive speed change of 12.26 m/s^2 (equivalent to 44.14 (km/h)/s) for 0.01 s, which means an increase of 0.44 km/h in speed, and a negative speed change of 14.55 m/s^2 (equivalent to a decrease of 0.52 km/h in speed).

3.3. Impacts Cluster

The impacts, or G-forces, that players endure during competition are a revealing variable of the demands of the competition, extensively studied by researchers. Table 7 displays the results of the two-step cluster analysis, where results are unconditionally grouped into two clusters, categorized as Moderate and High. A high number of impacts per minute predominate in the competition (59.9%), which shows that basketball players bear a high stress due to gravity, contact with other players, and the types of movements they perform during the games (jumps, changes of direction, starts, braking, etc.). It is important to note that these values are normalized to game time.

In order to achieve greater discrimination in the thresholds of this kinematic variable, a five-range cluster analysis was also performed (Table 8). The K-means cluster analysis identifies five distinct groups of impacts per minute (imp/min) (F = 593.048; df 4; $p < 0.001$), with significant differences between each of the five groups. The results reveal that moderate impacts (120.53 to 143.60 imp/min) predominate the most in basketball games (33.07%). Moreover, there is a trend towards enduring higher loads, identifying moments when players experience high stress (26.46%) and very high load (14.01%). Sequences of high intensity are observed, caused by game actions involving contact with other players or specific movements such as jumps (rebounds or blocks) and changes in speed (defensive movements, off-ball movements, etc.).

Table 7. Results of the two-step neuromuscular OEL cluster impacts/min.

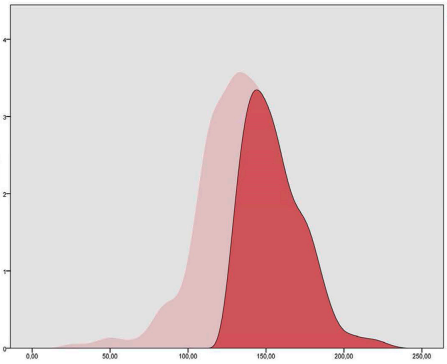
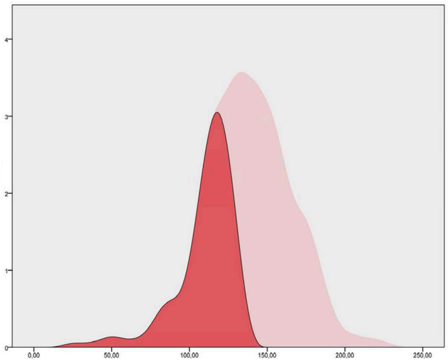
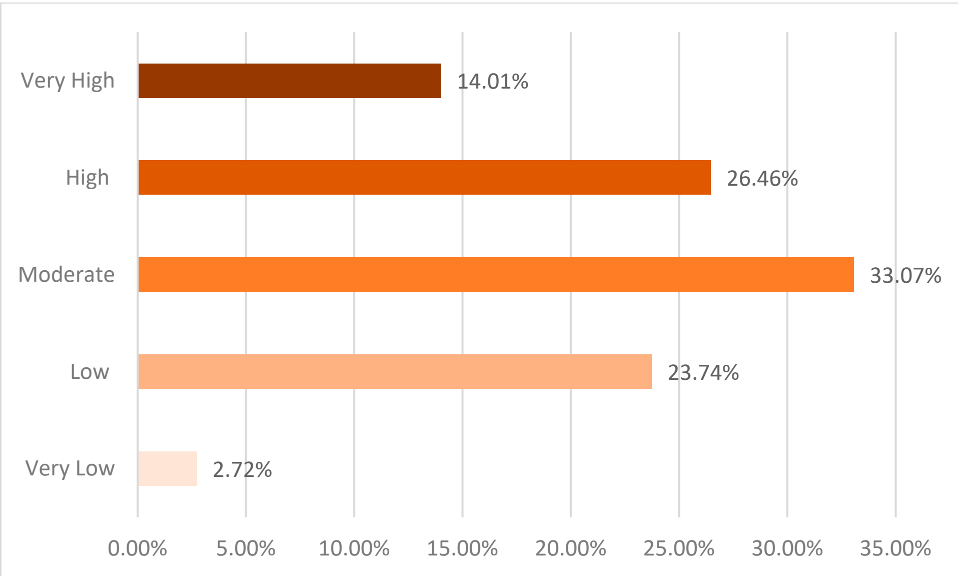
Impacts/min (G-force)	Moderate	High
Centers	110.03	155.62
Ranges	27.50 to 130.75	131.00 to 223.47
%	40.1%	59.9%
Distribution		

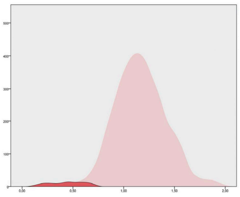
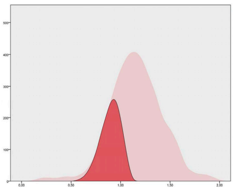
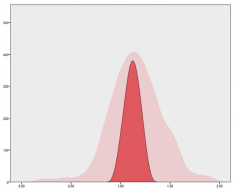
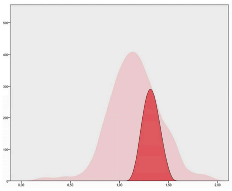
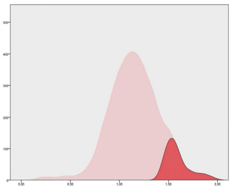
Table 8. Five-k means neuromuscular OEL cluster results for impacts/min.

IMP/min	Very Low	Low	Moderate	High	Very High
Centers	57.45	107.40	132.01	155.10	182.69
Ranges	27.50 to 78.00	83.22 to 119.60	120.53 to 143.60	143.81 to 169.14	169.43 to 223.47
n	7	61	85	68	36
Distribution					

3.4. Player Load/min Cluster

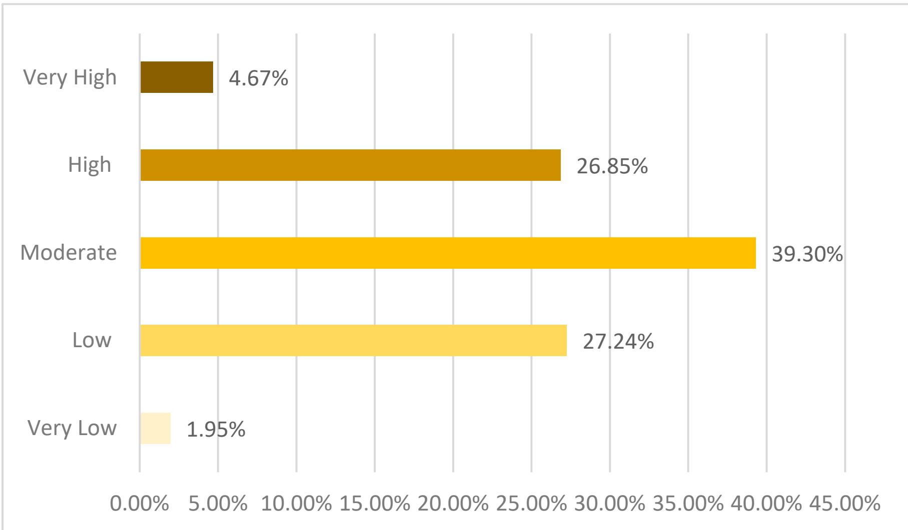
Finally, the results of the thresholds of the variable Player Load/min are presented (Table 9). Unconditionally, five groups were identified, showing a "normal" distribution, indicating that a basketball match requires players to sustain a moderate load (32.3%) with periods of higher and lower demand. Moreover, it is essential to highlight that there are moments when the demands are very high (12.8%).

Table 9. Neuromuscular OEL two-step cluster results for Player Load/min.

PL/min	Very Low	Low	Moderate	High	Very High
Centers	0.44	0.90	1.12	1.32	1.59
Ranges	0.19 to 0.64	0.65 to 1.01	1.02 to 1.21	1.22 to 1.43	1.44 to 1.93
%	2.7%	26.5%	32.3%	25.7%	12.8%
Distribution					

Following the same procedure used with the previous variables, a five-range cluster analysis was conducted for Player Load/min (Table 10). Five thresholds of Player Load/min were identified using K-means clustering (F = 528.051; df 4; $p < 0.001$), with significant differences between each of the five groups. The results obtained with this classification system are similar to the previous one, confirming that, in basketball games, there are moments of high-intensity load (1.72 au/min) amidst moderate intensities, with fluctuating periods of increase and decrease. These values can serve as a reference for designing tasks with higher or lower demand on the players.

Table 10. Results of the Cluster five-k means of neuromuscular OEL Player Load/min.

PL/min	Very Low	Low	Moderate	High	Very High
Centers	0.36	0.89	1.14	1.40	1.72
Ranges	0.19 to 0.50	0.51 to 1.01	1.02 to 1.27	1.28 to 1.56	1.57 to 1.93
n	5	70	101	69	12
Distribution					

4. Discussion

The objective of this research was to determine the objective external load demands during a basketball competition of five variables, three kinematic (speed, accelerations, and decelerations) and two neuromuscular variables (impacts/min and Player Load/min), and subsequently establish workload ranges. There is no evidence of differences in the classification of external load demands when using a mathematical model not conditioned by the researcher (two-step cluster) or when classifying according to the expert's criteria (k-means cluster). Likewise, an additional objective was established to analyze the results using two different types of mathematical models (two-step and k-means clustering) to identify the best classification criterion. The results have allowed the characterization of the workload demands endured by professional basketball players, as well as the thresholds in which their responses can be classified.

Different studies have tried to analyze the activity of a basketball game, as well as the rhythms at which the player moves. Some authors have classified the speed of displacement in four categories (Standing-Walking, Jogging, Running, and Sprinting) [6,32,42], while other authors established five categories (Standing, Walking, Jogging, Running, and Sprinting) [8,31,33]. All these studies propose different reference values, due to the different methodologies used in the studies, the sex of the samples, and the competitive levels. In this research, two classification techniques were applied to identify the work ranges: on the one hand, in an unconditioned manner, and on the other hand, establishing five groups. The data obtained from the movement speed of male professional basketball players during the official competition of the present study, using the two classification techniques, differ especially regarding the highest values, those related to the speed used in the maximum actions (high-intensity running and sprinting). In the two-step cluster, such actions are those performed from 10.63 km/h, while in the five-group K-means cluster, the highest speed actions were established from 12.72 km/h (up to 17.50 km/h in the case of high-intensity running and from 17.51 km/h in the case of sprinting). These data seem to be more in line with those obtained by some authors in the literature [9,32] and appreciably lower than the reference values provided by the companies that sell inertial devices, which are based on values from professional men's soccer players. It seems difficult to obtain very-high-speed values in current basketball, and this may be due to the fact that both the distance of the court and the fact of making such displacement compatible with technical-tactical actions and with modifications of the run (i.e., changes of direction), together with the high load of impacts and contacts between players, make it impossible to reach higher values.

It is true that some contradictory results are also observed when analyzing the studies of Scanlan et al. [6] and Vázquez-Guerrero et al. [31], which offer higher values of speed (above 24 km/h). However, it should be noted that in the case of the Scanlan et al. [6] study, the data are obtained from a time and motion analysis performed on video; while in the case of Vázquez-Guerrero et al. [31], despite the data being obtained with inertial technology, the speed ranges (defined from the literature) were previously established, with very few values being recorded in the higher speed range. In this regard, it is worth noting that it should be relevant to assess not only the speed achieved but also the time spent at that speed [43]. Previous research in team sports stipulates that, in order to consider an action as a sprint, it has to occur in a period longer than one second [44,45], while other studies do not establish the duration for a sprint to occur [46,47]. Modern local positioning systems, LPS, are employed in invasion games that take place in enclosed spaces that employ a high sampling frequency, allowing these speed peaks to be identified in fractions of less than a second. This type of information is more accurate, and its use should be generalized in sports such as basketball in order to customize the load demands of the players.

Once the speed ranges have been defined, the researchers define the parameters associated with this variable. From the results of this study, it is proposed that, for professional male basketball players, sprinting can be considered when they move at a speed greater than 19 km/h. In addition, it is proposed that HSRs occur at more than 17.5 km/h.

Another aspect that is the subject of research is the percentage of distance covered at each specific speed threshold. Traditionally, it has been observed that the player spends between 23.4 and 66.3% of the time standing or walking; jogging between 5.6 and 36.3% of the time; running between 4.5 and 33.2%; and sprinting between 0.3 and 8.5% [48–50]. In the case of the present research, the results obtained support these data, both in the two-step cluster model in which the percentage of time spent moving at high intensity or sprinting is 9.1% and in the k-means cluster model in which such displacements reach 5.6% (between running and sprinting). Men's professional basketball is defined as a sport in which players move at medium-low intensity for a large part of the game, with very short periods of high intensities. This modulation should be known by coaches in order to design training tasks in which, during a continuous movement, high speed peaks are included.

Relating these data to the results obtained in the analysis of the acceleration and deceleration variables, it can also be observed that, regardless of the mathematical model used, the percentage of abrupt accelerations or decelerations exceeding 2 m/s^2 of high intensity is very low (around 5.2% for accelerations in the two-steps cluster, with no precise classification for decelerations in this model; the k-means cluster model for accelerations is 1.09% and for decelerations it is 3.25%). With a population of professional female basketball players, Ibáñez et al. [8] identified this same trend of many low-intensity accelerations and decelerations and few high-intensity ones. In addition, a very relevant data outcome of this analysis is to verify that accelerations and decelerations of different intensities, moderate, high, and very high, are produced, this observation being necessary to design tasks that can reproduce this type of abrupt speed variation. Changes of pace are fundamental in modern basketball. Having the ability to increase or decrease speed abruptly allows a player to overcome the opponent. This explosive work should be included in the specific training routines with the ball, as it will allow players to overcome the opponents. In addition, it is necessary to prepare the body for this type of specific efforts.

When considering accelerometry data collected during elite competition, in most research, it can be found that they divide such actions between total accelerations or decelerations and high intensity accelerations or decelerations [51,52]. In the case of high-intensity accelerations, it is again observed that the criterion to classify them as such varies depending on the research, the criterion to qualify them as such being, in the case of Svilar et al. [16], when the acceleration is >3.5 m/s^2, while in the case of Vázquez-Guerrero et al. [52], the criterion is above 3 m/s^2. The same criteria were established for high-intensity decelerations. Again, the same controversy arises, such that the most current results lead to the understanding that such criteria were not adequate for basketball, and that ranges, in this case of high-intensity accelerations and decelerations, need to be established in a much more personalized way for each team and/or player. As suggested by Petway et al. [53], it seems clear that further research on this topic is needed before a clear picture of acceleration and deceleration demands can be drawn. The results of this research have highlighted the specific demands of professional male basketball players. From these data, coaches will design specific tasks that can resemble the demands of official competition. For example, during game warm-ups, physical trainers should include tasks involving abrupt accelerations and decelerations to adapt the metabolism to the demands of competition.

The impacts, or G-forces, that players bear during competition represent a variable that reveals the demands of competition and that has begun to be studied in invasion games. The recording of a G-force can occur for different reasons, such as sudden changes in speed, direction, jumps, landings, or contact with other players. In this research, the sum of impacts received by a player during the competition per minute was used as the study variable. The results showed, with the two types of classification, a high tendency in terms of the level of G-forces that players endure during competition. There is a greater deviation of impacts towards high impacts (26.46%) and very high impacts (14.01%) than on low or very low values. There are few studies that quantify the impacts in basketball players, with many of them using high-intensity impacts. Ibáñez, Gómez-Carmona et al. [8] defined intensity ranges for women's professional basketball but not the quantity. With a population of female basketball players, a decrease in the number of impacts/min has been identified when the number of players increases in competition, e.g., in three vs. three and five vs. five competition [54]. This decrease also occurs between full games in competition, training, and small side games [55]. It has been shown that the amount and magnitude of impacts received by professional players during competition is very high. Small side games and full games during training are able to provoke demands similar to those of competition, so coaches should maintain their training routines. The design of reduced training tasks of high intensity, with contacts, or intense full games allows a correct preparation of the players.

The identification of neuromuscular external load demands through the Player Load variable is beginning to occur in basketball. This variable allows us to identify the load that the athlete supports from the variation of the accelerometry in the three planes of movement. Therefore, for many researchers, it is beginning to be a variable to be used for load control as a positive correlation has been identified between the Player Load and the objective internal load [54,56] and the subjective external load [55]. Scanlan et al. [57] established six ranges of Player Load intensity using individualized and fixed thresholds. Their results revealed that more than 98% of the load occurs at low intensities, while only 2% occurred at high intensities during training. Regardless of the intensity ranges, as they come from devices using different algorithms for the calculation of the Player Load [25], the results reported from professional competition show a distribution of cases similar to normality, with a predominance of the percentage of cases in a normal range (40%), over 27% of cases in low and high values, and with 5% of cases in very high values. The high-intensity peaks are the most interesting for coaches, since the technical-tactical actions that provoke them should be identified in order to design training situations that reproduce them. Likewise, during the monitoring of training sessions, coaches should know when players are working at these intensities, so as not to produce excessive overloads that can increase the risk of injury. Of the five variables analyzed, only in Player Load/min did the cluster analysis coincide in the number of groups according to the intensity range regardless of the technique used, conditioned and unconditioned.

Basketball is an acyclic sport, characterized by intermittent efforts where players undergo constant transitions between low- and high-intensity movements [50]. During the game, activities of continuous low intensity, such as walking or jogging, predominate, interspersed with critical moments that demand high-intensity actions such as running, maximum sprints, jumps, turns, and other explosive movements [21]. This unpredictable combination of efforts presents a unique challenge for the physical preparation of basketball players. Coaches must prepare players not only for the average physiological load but also for the most demanding scenarios they may encounter during competition [53]. Therefore, it is essential to understand the maximum external loading ranges in different kinematic and neuromuscular variables for the strengthening and preparation of basketball players, providing a scientific foundation for sport-specific preparation.

Having objective information about the kinematic and neuromuscular external loading demands of professional basketball players will enable coaches at this level to design training interventions specifically tailored to meet these sport-specific demands [58]. The design of speed, acceleration, deceleration, and change of direction exercises should target the kinematic intensities observed during live play [21], taking into account the principle of specificity in sports training [59], which proposes that an athlete's preparation should closely match the competitive demands of the sport. Load ranges from other sports, performance levels, or genders are not applicable to this population.

Understanding the kinematic and neuromuscular external loading demands during competition and implementing a proper warm-up tailored to these needs is also crucial for the prevention of injuries in basketball players [60]. Training loads should be adjusted to the demands of competition, establishing thresholds and work times for personalized training, as well as setting specific recovery protocols for each athlete [61]. Establishing training loads according to the identified competition levels for a specific population of players ensures a safe progression in training.

Finally, this study has used two different techniques to classify the load demands of professional basketball players. This practice is not very common in the sports context, since it requires prior data collection to establish the groups [8], although it subsequently allows a better interpretation of the results, adapted to the population, team, or player under study, and personalization of the training proposals [57]. The two clustering techniques used, two-step clustering and k-means clustering, have revealed the existence of different groups in the four external load variables analyzed, namely speed, accelerations, decelerations, and impacts, presenting the same groups in the neuromuscular variable of

Player Load. Although the results of two-step clustering are more robust from a mathematical point of view [38], from a practical point of view, so that coaches can design tasks with a greater range of discrimination, five-rank k-means clustering is an interesting alternative. In both cases, reference values are provided that should be taken into account by the trainers, depending on the objective of their intervention or the degree of accuracy in their practical proposals.

5. Study Limitations

In the present investigation, some limitations have been identified during the development of the research and in the elaboration of the manuscript.

The characteristics of official basketball competitions, which preclude the use of inertial devices on players, limit the amount of data that can be obtained. Our sample comes from an official preparatory competition of professional basketball players. In future studies, the sample should be expanded.

Another limitation is found in the few studies that use the classification system based on mathematical criteria (two-step clustering) to establish the working thresholds in sports science, conditioning the discussion of this study. Existing studies use samples of players of lower competitive level and age or come from samples of female basketball players.

6. Conclusions and Practical Applications

The present study has allowed the characterization of the kinematic and neuromuscular external load demands of professional basketball players during official competition by establishing load distribution ranges. The traditional speed thresholds established in the literature, specifically those related to very-high-intensity and/or sprint actions, should be modified. Data higher than 24 km/h are not usually observed, so it seems appropriate to establish new ranges, encompassing maximum intensity actions from 17.5 km/h and sprints at 19 km/h.

In relation to accelerations or decelerations, the data obtained reflect the same controversy. Accelerations or decelerations exceeding 2 m/s^2 are barely observed, not being in accordance with the traditionally established ranges. The most recent results lead us to understand that these criteria were not adequate for basketball, and that it is necessary to establish ranges in a much more personalized way for each team and/or player.

This research overcomes the traditional limitation observed in the literature specific to the thresholds of kinematic variables in basketball and offers a useful tool for the coach and physical trainer, in such a way that allows to have a closer knowledge of the reality when designing training sessions.

In relation to the neuromuscular variables recorded (impacts and Player Load), the results lead us to consider basketball as a fundamentally neuromuscular sport, where high-intensity impacts or high- and very-high-intensity Player Load represent a high percentage.

In view of the results obtained, and noting that, in most of the literature, basketball is defined as an intermittent sport, mainly from the analysis of kinematic variables, this definition should be reconsidered, being more accurate to understand basketball as a sport with a high neuromuscular load.

The methodology of data analysis and classification (cluster analysis of the variables recorded during the competition) allows for a more precise knowledge adapted to the specific circumstances of each team and each player.

In relation to the clustering methods used, two-step clustering and k-means clustering, different results are obtained for both kinematic variables and impacts, but not for the Player Load analysis. The use of these clustering techniques will depend on the objective of the study, using a mathematical criterion to classify or a criterion based on expert judges. While two-step clustering may offer a more robust model, from a practical point of view, the groupings proposed by this model may not discriminate enough for the work of the trainers, making it necessary to use k-means clustering. The classification system based on expert judgment, defining five thresholds, allows a greater discrimination of the type of tasks by always establishing five groups. The work thresholds derived from the mathematical cluster offers the coach a more uniform type of tasks.

Based on these conclusions, the following practical applications can be established:

1. The traditionally established thresholds of kinematic variables, especially those referring to maximum intensity, do not really reflect the reality of competitive basketball. Therefore, it is necessary to establish new speed thresholds, based on the data obtained in competition, which allow a more concise customization of the different ranges of work, depending on the characteristics of each team (competitive level, sex, age) and each player.
2. Since it is known that the competitive activity experienced by players is highly conditioned by different factors (gender, age, competitive level, etc.), future research on this topic could allow the establishment of speed ranges according to specific positions, gender, competition, etc., and thus, significantly improve the training processes.
3. The high demands for accelerations and decelerations identified in these athletes suggest that specific lower-body strength training should be implemented to minimize the risk of injuries. Additionally, this strength training should be complemented with specific postural stability work for the lower limb joints.
4. In any case, observing the results obtained under the perspective of maximum demand scenarios, it will be necessary to design tasks with a specific time frame that include high-intensity actions and/or sprints, together with accelerations and decelerations of moderate intensity, and high- and very-high-intensity. In the design of a task, the duration of time will be established, and it will be controlled so that the players reach those maximum physical demands, taking into account the reference values of each population of players, to guarantee adequate preparation for what they will have to face during the official competition.
5. Coaches, when designing training sessions, and depending on their duration, should integrate the concept of maximum demand scenarios into the tasks, e.g., controlling the exposure time of a speed range within a time window, aiming to, during a defined time, reach the proposed speed peaks.
6. The high level of neuromuscular load experienced by a basketball player during competition, both in relation to the impacts and the Player Load, makes it necessary to review the recovery protocols, as well as the distribution of the training contents, adapting the weekly microcycle of competition to this reality.
7. Based on the different Player Load thresholds obtained and on the maximum demand scenarios, a weekly distribution of these scenarios could be established to provide the different types of stimuli throughout the competitive microcycle.
8. The proposed Player Load thresholds should also be considered when designing recovery processes for sports injuries, and even establish them as indicators to consider a player fit or unfit to return to competition.
9. The software linked to the inertial devices with which the data are recorded allows the customization of the working ranges for obtaining preliminary reports of the monitored training and competitions. These reference data can be used to customize the intensity ranges of the kinematic variables.
10. As an example, the SVIVO application of the company Realtrack System (devices used in this research) allows a real-time visualization of the variables. Specifically, the Player Load information is displayed. Physical trainers can identify, during training and competition, when a player starts to be in a zone of high-intensity load (1.59 au/min), being a first referential approximation to identify the real load of a task or a moment of high physical demand during the competition.

Finally, it is necessary to indicate that we are at an incipient stage of research, due to the absence of data collected during competition. Therefore, it is necessary to continue overcoming the limitations established by sports organizations and collect information on official competitions of different basketball populations to improve the scientific knowledge of this sport. Furthermore, after identifying the work ranges for professional male basketball players, it is necessary to customize the work ranges to the playing positions in order to adapt the training processes. The research has revealed the existence of differences in game actions and load demands of the players per playing positions during competition. Therefore, to adapt training to playing positions, it will be necessary to identify the differences in external load demands in this population of players. Thus, training will be more personalized and specific.

Another line of research derived from this study will be the specific analysis of these variables during periods of maximum demand, as it has been proven that basketball is an endless sport of moderate intensity with windows of high intensity. The new thresholds should be applied in these time periods to provide a more precise knowledge of what happens during competition.

Author Contributions: Conceptualization, S.J.I. and P.L.-S.; methodology, S.J.I.; software, S.J.I.; formal analysis, S.J.I. and P.L.-S.; investigation, P.L.-S. and A.L.; data curation, S.J.I. and P.L.-S.; writing—original draft preparation, S.J.I.; writing—review and editing, P.L.-S., A.L. and S.F.; visualization, P.L.-S., A.L. and S.F.; supervision, S.F.; project administration, S.J.I.; funding acquisition, S.J.I. and S.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research has been partially subsidized by the Spanish National Agency of Investigation through the project "Scientific and Technological Support to analyze the Training Workload of Basketball teams according to sex, level of the players and season period" (PID2019-106614GBI00) MCIN/AEI/10.13039/501100011033.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Universidad de Extremadura (no. 233/2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is not available due to ethical restrictions.

Acknowledgments: This work was developed within the Group of Optimization of Training and Sports Performance (GOERD) of the Faculty of Sports Sciences of the University of Extremadura. All authors have contributed to the manuscript, and we certify that it has not been published and is not under consideration for publication in another journal.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Roman, P.A.L.; Macias, F.J.V.; Pinillos, F.G. Effects of a contrast training programme on jumping, sprinting and agility performance of prepubertal basketball players. *J. Sports Sci.* **2018**, *36*, 802–808. [CrossRef]
2. Schelling, X.; Torres, L. Accelerometer Load Profiles for Basketball-Specific Drills in Elite Players. *J. Sports Sci. Med.* **2016**, *15*, 585–591.
3. Arede, J.; Ferreira, A.P.; Esteves, P.; Gonzalo-Skok, O.; Leite, N. Preparing for the youth basketball European Championship: Perceptual response and acute effects of an injury prevention program. *Int. J. Sports Sci. Coach.* **2022**. [CrossRef]
4. Khan, M.; Madden, K.; Burrus, M.T.; Sikka, R.; Bedi, A. Epidemiology and Impact on Performance of Lower Extremity Stress Injuries in Professional Basketball Players. *Sports Health-A Multidiscip. Approach* **2018**, *10*, 169–174. [CrossRef]
5. Caparros, T.; Casals, M.; Solana, A.; Pena, J. Low External Workloads Are Related to Higher Injury Risk in Professional Male Basketball Games. *J. Sports Sci. Med.* **2018**, *17*, 289–297.
6. Scanlan, A.T.; Tucker, P.S.; Dascombe, B.J.; Berkelmans, D.M.; Hiskens, M.I.; Dalbo, V.J. Fluctuations in activity demands across game quarters in professional and semiprofessional male basketball. *J. Strength Cond. Res.* **2015**, *29*, 3006–3015. [CrossRef]
7. Gabbett, T.J.; Domrow, N. Relationships between training load, injury, and fitness in sub-elite collision sport athletes. *J. Sports Sci.* **2007**, *25*, 1507–1519. [CrossRef]
8. Ibáñez, S.J.; Gómez-Carmona, C.D.; Mancha-Triguero, D. Individualization of Intensity Thresholds on External Workload Demands in Women's Basketball by K-Means Clustering: Differences Based on the Competitive Level. *Sensors* **2022**, *22*, 324. [CrossRef]
9. Reina, M.; García-Rubio, J.; Esteves, P.T.; Ibáñez, S.J. How external load of youth basketball players varies according to playing position, game period and playing time. *Int. J. Perform. Anal. Sport* **2020**, *20*, 917–930. [CrossRef]
10. Salazar, H.; Castellano, J.; Svilar, L. Differences in External Load Variables Between Playing Positions in Elite Basketball Match-Play. *J. Hum. Kinet.* **2020**, *75*, 257–266. [CrossRef]

11. Ibáñez, S.J.; Piñar, M.I.; García, D.; Mancha-Triguero, D. Physical Fitness as a Predictor of Performance during Competition in Professional Women's Basketball Players. *Int. J. Environ. Res. Public Health* **2023**, *20*, 988. [CrossRef]
12. Power, C.J.; Fox, J.L.; Dalbo, V.J.; Scanlan, A.T. External and Internal Load Variables Encountered During Training and Games in Female Basketball Players According to Playing Level and Playing Position: A Systematic Review. *Sports Med.-Open* **2022**, *8*, 107. [CrossRef]
13. Reina, M.; Mancha-Triguero, D.; Ibáñez, S.J. Monitoring of a competitive microcycle in professional women's basketball through inertial devices. *Rev. Int. Med. Cienc. Act. Fis. Deporte* **2022**, *22*, 663–685. [CrossRef]
14. Reina, M.; García-Rubio, J.; Ibáñez, S.J. Training and Competition Load in Female Basketball: A Systematic Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2639. [CrossRef]
15. Scanlan, A.T.; Wen, N.; Tucker, P.S.; Dalbo, V.J. The relationships between internal and external training load models during basketball training. *J. Strength Cond. Res.* **2014**, *28*, 2397–2405. [CrossRef]
16. Svilar, L.; Castellano, J.; Jukic, I. Load monitoring system in top-level basketball team: Relationship between external and internal training load. *Kinesiology* **2018**, *50*, 25–33. [CrossRef]
17. Piedra, A.; Pena, J.; Caparros, T. Monitoring Training Loads in Basketball: A Narrative Review and Practical Guide for Coaches and Practitioners. *Strength Cond. J.* **2021**, *43*, 12–35. [CrossRef]
18. Piñar, M.I.; García, D.; Mancha-Triguero, D.; Ibáñez, S.J. Effect of Situational and Individual Factors on Training Load and Game Performance in Liga Femenina 2 Basketball Female Players. *Appl. Sci.* **2022**, *12*, 7752. [CrossRef]
19. Buchheit, M.; Lacome, M.; Cholley, Y.; Simpson, B. Neuromuscular Responses to Conditioned Soccer Sessions Assessed via GPS-Embedded Accelerometers: Insights Into Tactical Periodization. *Int. J. Sports Physiol. Perform.* **2018**, *13*, 577–583. [CrossRef]
20. Portes, R.; Navarro, R.M.; Sosa, C.; Trapero, J.J.; Jimenez, S.L. Monitoring and Interpreting External Load in Basketball: A Narrative Review. *Rev. Psicol. Deporte* **2019**, *28*, 119–131.
21. Stojanovic, E.; Stojiljkovic, N.; Scanlan, A.T.; Dalbo, V.J.; Berkelmans, D.M.; Milanovic, Z. The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. *Sports Med.* **2018**, *48*, 111–135. [CrossRef]
22. Varley, M.C.; Jaspers, A.; Helsen, W.F.; Malone, J.J. Methodological Considerations When Quantifying High-Intensity Efforts in Team Sport Using Global Positioning System Technology. *Int. J. Sports Physiol. Perform.* **2017**, *12*, 1059–1068. [CrossRef]
23. Espasa-Labrador, J.; Fort-Vanmeerhaeghe, A.; Montalvo, A.M.M.; Carrasco-Marginet, M.; Irurtia, A.; Calleja-Gonzalez, J. Monitoring Internal Load in Women's Basketball via Subjective and Device-Based Methods: A Systematic Review. *Sensors* **2023**, *23*, 4447. [CrossRef]
24. Ibáñez, S.J.; Feu, S.; Cañadas, M. Integral analysis system of training tasks, SIATE, in invasion games. *E-Balonmano.com* **2016**, *12*, 3–30.
25. Gómez-Carmona, C.D.; Bastida-Castillo, A.; Ibáñez, S.J.; Pino-Ortega, J. Accelerometry as a method for external workload monitoring in invasion team sports. A systematic review. *PLoS ONE* **2020**, *15*, e0236643.
26. Ibáñez, S.; Antúnez, A.; Pino, J.; García-Rubio, J. Control del entrenamiento mediante el empleo de tecnologías en tiempo real en balonmano. In *Avances Científicos para el Aprendizaje y Desarrollo del Balonmano*; Feu, S., García-Rubio, J., Ibáñez, S., Eds.; Universidad de Extremadura: Cáceres, Spain, 2018; Volume Monografía 3, pp. 167–192.
27. González-Espinosa, S.; Antúnez, A.; Feu, S.; Ibáñez, S.J. Monitoring the External and Internal Load Under 2 Teaching Methodologies. *J. Strength Cond. Res.* **2020**, *34*, 2920–2928. [CrossRef]
28. García-Ceberino, J.M.; Antúnez, A.; Feu, S.; Ibáñez, S.J. Quantification of Internal and External Load in School Football According to Gender and Teaching Methodology. *Int. J. Environ. Res. Public Health* **2020**, *17*, 344. [CrossRef]
29. Gamero, M.G.; García-Ceberino, J.M.; Ibáñez, S.J.; Feu, S. Influence of the Pedagogical Model and Experience on the Internal and External Task Load in School Basketball. *Int. J. Environ. Res. Public Health* **2021**, *18*, 11854. [CrossRef]
30. Reina, M.; García-Rubio, J.; Ibáñez, S.J. Activity Demands and Speed Profile of Young Female Basketball Players Using Ultra-Wide Band Technology. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1477. [CrossRef]
31. Vázquez-Guerrero, J.; Fernández-Valdes, B.; Jones, B.; Moras, G.; Reche, X.; Sampaio, J. Changes in physical demands between game quarters of U18 elite official basketball games. *PLoS ONE* **2019**, *14*, e0221818. [CrossRef]
32. Sosa, C.; Lorenzo, A.; Trapero, J.; Ribas, C.; Alonso, E.; Jimenez, S.L. Specific Absolute Velocity Thresholds during Male Basketball Games Using Local Positional System; Differences between Age Categories. *Appl. Sci.* **2021**, *11*, 4390. [CrossRef]
33. Puente, C.; Abian-Vicen, J.; Areces, F.; Lopez, R.; Del Coso, J. Physical and Physiological Demands of Experienced Male Basketball Players During a Competitive Game. *J. Strength Cond. Res.* **2017**, *31*, 956–962. [CrossRef]
34. Vázquez-Guerrero, J.; Reche, X.; Cos, F.; Casamichana, D.; Sampaio, J. Changes in External Load When Modifying Rules of 5-on-5 Scrimmage Situations in Elite Basketball. *J. Strength Cond. Res.* **2020**, *34*, 3217–3224. [CrossRef]
35. Leicht, A.S.; Fox, J.; Connor, J.; Sargent, C.; Sinclair, W.; Stanton, R.; Scanlan, A. External Activity Demands Differ Between Referees and Players During a Sub-Elite, Men's Basketball Match. *Res. Q. Exerc. Sport* **2019**, *90*, 720–725. [CrossRef]
36. Ibáñez, S.J.; Feu, S.; Antúnez, A.; Arenas, M.A.; López, P. La investigación sobre baloncesto. Qué aporta el CIB y la Ciencia al Baloncesto. In *Ciencia y Práctica en Baloncesto, una Relación de Presente y Futuro*; Ibánez, S.J., García-Rubio, J., Eds.; Universidad de Extremadura: Cáceres, Spain, 2022; Volume 8, pp. 13–36.
37. Houtmeyers, K.C.; Jaspers, A.; Figueiredo, P. Managing the Training Process in Elite Sports: From Descriptive to Prescriptive Data Analytics. *Int. J. Sports Physioly Perform.* **2021**, *16*, 1719–1723. [CrossRef]
38. Aldenderfer, M.; Blashfield, R. *Cluster Analysis*; Sage Publications: Newbury Park, CA, USA, 1984.

39. Ato, M.; Vallejo, G. *Diseños de Investigación en Psicología*; Ediciones Pirámide: Madrid, Spain, 2016.
40. Montero, I.; Leon, O.G. A guide for naming research studies in Psychology. *Int. J. Clin. Health Psychol.* **2007**, *7*, 847–862.
41. Pino-Ortega, J.; Bastida-Castillo, A.; Gomez-Carmona, C.D.; Rico-Gonzalez, M. Validity and reliability of an eight antennae ultra-wideband local positioning system to measure performance in an indoor environment. *Sports Biomech.* 2020, *Online ahead of print*. [CrossRef]
42. Pérez-Chao, E.A.; Gómez, M.A.; Lisboa, P.; Trapero, J.; Jiménez, S.L.; Lorenzo, A. Fluctuations in External Peak Demands across Quarters during Basketball Games. *Front. Physiol.* **2022**, *13*, 868009. [CrossRef]
43. Sweeting, A.J.; Cormack, S.J.; Morgan, S.; Aughey, R.J. When Is a Sprint a Sprint? A Review of the Analysis of Team-Sport Athlete Activity Profile. *Front. Physiol.* **2017**, *8*, 432. [CrossRef]
44. Carling, C.; Le Gall, F.; Dupont, G. Analysis of repeated high-intensity running performance in professional soccer. *J. Sports Sci.* **2012**, *30*, 325–336. [CrossRef]
45. Clarke, A.C.; Anson, J.; Pyne, D. Physiologically based GPS speed zones for evaluating running demands in Women's Rugby Sevens. *J. Sports Sci.* **2015**, *33*, 1101–1108. [CrossRef]
46. Kempton, T.; Sullivan, C.; Bilsborough, J.C.; Cordy, J.; Coutts, A.J. Match-to-match variation in physical activity and technical skill measures in professional Australian Football. *J. Sci. Med. Sport* **2015**, *18*, 109–113. [CrossRef]
47. Varley, M.C.; Gabbett, T.; Aughey, R.J. Activity profiles of professional soccer, rugby league and Australian football match play. *J. Sports Sci.* **2014**, *32*, 1858–1866. [CrossRef]
48. Delextrat, A.; Badiella, A.; Saavedra, V.; Matthew, D.; Schelling, X.; Torres-Ronda, L. Match activity demands of elite Spanish female basketball players by playing position. *Int. J. Perform. Anal. Sport* **2015**, *15*, 687–703. [CrossRef]
49. Matthew, D.; Delextrat, A. Heart rate, blood lactate concentration, and time-motion analysis of female basketball players during competition. *J. Sports Sci.* **2009**, *27*, 813–821. [CrossRef]
50. Scanlan, A.T.; Dascombe, B.J.; Reaburn, P.; Dalbo, V.J. The physiological and activity demands experienced by Australian female basketball players during competition. *J. Sci. Med. Sport* **2012**, *15*, 341–347. [CrossRef]
51. Svilar, L.; Castellano, J.; Jukic, I. Comparison of 5vs5 training games and match-play using microsensor technology in elite basketball. *J. Strength Cond. Res.* **2019**, *33*, 1897–1903. [CrossRef]
52. Vázquez-Guerrero, J.; Suárez-Arrones, L.; Gómez, D.C.; Rodas, G. Comparing external total load, acceleration and deceleration outputs in elite basketball players across positions during match play. *Kinesiology* **2018**, *50*, 228–234. [CrossRef]
53. Petway, A.J.; Freitas, T.T.; Calleja-González, J.; Leal, D.M.; Alcaraz, P.E. Training load and match-play demands in basketball based on competition level: A systematic review. *PLoS ONE* **2020**, *15*, e0229212. [CrossRef]
54. Reina, M.; García-Rubio, J.; Antúnez, A.; Ibáñez, S.J. Comparison of internal and external load in official 3 vs. 3 and 5 vs. 5 female basketball competitions. *Retos* **2020**, *37*, 400–405.
55. Reina, M.; Mancha, D.; Feu, S.; Ibáñez, S.J. Is training carried out the same as competition? Analysis of load in women's basketball. *Rev. Psicol. Deporte* **2017**, *26* (Suppl. S1), 9–13.
56. Fox, J.L.; O'Grady, C.J.; Scanlan, A.T. The Relationships Between External and Internal Workloads during Basketball Training and Games. *Int. J. Sports Physiol. Perform.* **2020**, *15*, 1081–1086. [CrossRef]
57. Scanlan, A.T.; Fox, J.L.; Milanovic, Z.; Stojanovic, E.; Stanton, R.; Dalbo, V.J. Individualized and Fixed Thresholds to Demarcate PlayerLoad Intensity Zones Produce Different Outcomes. *J. Strength Cond. Res.* **2021**, *35*, 2046–2052. [CrossRef]
58. Heishman, A.D.; Daub, B.D.; Miller, R.M.; Freitas, E.D.S.; Bemben, M.G. Monitoring External Training Loads and Neuromuscular Performance for Division I Basketball Players over the Preseason. *J. Sports Sci. Med.* **2020**, *19*, 204–212.
59. Renshaw, I.; Davids, K.; Newcombe, D.; Roberts, W. *The Constraints-Led Approach: Principles for Sports Coaching and Practice Design*; Routledge: New York, NY, USA, 2019.
60. Davis, A.C.; Emptage, N.P.; Pounds, D.; Woo, D.; Sallis, R.; Romero, M.G.; Sharp, A.L. The Effectiveness of Neuromuscular Warmups for Lower Extremity Injury Prevention in Basketball: A Systematic Review. *Sports Med.-Open* **2021**, *7*, 67. [CrossRef]
61. Weiss, K.J.; Allen, S.V.; McGuigan, M.R.; Whatman, C.S. The Relationship Between Training Load and Injury in Men's Professional Basketball. *Int. J. Sports Physiol. Perform.* **2017**, *12*, 1238–1242. [CrossRef]