The Load Management Across Sports and a Sub-analysis

Junzhe Zhang[1](✉) and Liwei Zhang[2]

[1] Shanghai Pinghe School, Shanghai 201206, China
paulsonzhang@163.com
[2] Suzhou Foreign Language School, Suzhou 215011, China

Abstract. Load management is a skill that an athlete needs to have during a long period of exercise, which has a decisive impact on the recovery of the athlete's body. Each athlete gives adequate time for rest, but does this differ between different types of athletes, or does load management differ between players in the same sport but in different positions? Therefore, the purpose of our current study was to use data analysis to determine whether basketball and hockey players' playing time was affected by various factors throughout the season. The data were compiled, averaged, varied, and then compared with different algorithms, such as the T-test and the ANOVA-test, to determine if the physical load was similar across sports and if the players at different positions had different playing time data.

Keywords: Load management · T-test · ANOVA-test

1 Introduction

1.1 Background

"If the athlete isn't being physically stressed, you're wasting your time. I honestly believe that" [1]. Athletes need to constantly train to improve their athletic performance, but this can also be very taxing on their bodies. Therefore, load management plays a significant role to the athletes. Load management is defined as the intentional temporary reduction of external physiological stresses designed to promote overall improvements in athlete health and performance while maintaining musculoskeletal and metabolic health. When we analyzed the load management of athletes, we found that their stress was focused on the internal and external load. Internal load refers to the psychological and mental stress that athletes have to endure. The athletes' confidence may show psychological pressure during the match, and their heart rate variability may also be included in the internal load as the physiological stress. Both of these pressures can impact an athlete's performance on the field while they adjust their mental and physical state throughout the season or in the off-season. Moreover, the external load is counted based on the effort athletes paid into the training and games, such as their muscle endurance. This part of the fatigue can be felt more intuitively because it can be reflected by the data on the field and, at the same time, by their habits, such as the daily sleep time, which brings different degrees of recovery and exertion to their bodies.

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1.2 Purpose

The main purpose of our research on this topic is to analyze the load management that different athletes need to do throughout the season. Different sports cause different physical wear and tear on the athletes, so they have different exercise duration. Through an analysis of sports data, we aim to find which sport would cause more physical and mental strain on the athletes. At the same time, we also want to use such data to determine whether individual sports will bring more load or team sports will bring more load to the athletes. Furthermore, players play different roles and positions in the same team sport, and their playing times are different. Through the statistics, we want to determine if their position on the field is a decisive factor in their playing time.

1.3 Problem Restatement

Since we needed some variables and constants, we decided to focus on the athletes' external load, assuming that their mental and spiritual states are of a compatible level of health. This choice was made because we could more precisely compare the external load with the mobilization since these are documented in the data. This also makes it easier for us to present the final results. At the same time, the internal load of athletes is more difficult to measure than the external load, so we focus more on their physical stress, such as their playing time per game and attendance rate throughout the season. Therefore, in our study, the athletes' psychological state was not in our consideration. In individual sports like tennis, we counted the players who played the most in a whole year for comparison, while in basketball and hockey, we took into account the different positions needed for team sports, so we not only counted the players' playing time for the whole season but also listed their positions on the court separately.

Playing time is an important indicator of an athlete's physical attrition. It often represents an athlete's physical exertion, and the longer the playing time, the more physical energy the athlete expends. If the playing time is less, it also indicates that the physical exertion of this athlete is less. Therefore, we choose the athlete's playing time as a comprehensive and easily available indicator to reflect the athlete's body load.

1.4 Literature Review

According to the article "How to load management can improve sports performance," Load management is "a deliberate, temporary reduction of external physiological stressors intended to improve an athlete's wellness and performance. By reducing the amount of training and competition an athlete takes, you help them recover, reduce injury risk factors and perform better over the long term" [2].

Load management is critical for athletes. There is nothing more crucial than temporary rest and adjustment to achieve a more long-term stable performance in the long run because when the athlete's body perceives fatigue, and at this time, often they are not able to play at their best. So, athletes need to reduce their training or get enough sleep to get their bodies back to a better physical level to be ready for future competitions.

From the article "What Is 'Load Management' and Why Does it Matter for Athletes?", we learn that de-loading periods, also known as "unloading" or "offloading," are characterized by a deliberately planned reduction in one or several parameters, including frequency, intensity, time and type of activity. Load management might be a term that's taken on some negative connotations. Still, the truth is that it's hugely important for any athlete looking to compete at a high level and stay injury-free consistently [3].

For those athletes who want to maintain a good level of play at a high level, it is crucial to reduce the load reasonably. Given that excessive fatigue can lead to an increased risk of injury, in the long run, proper rest and reasonable offloading will both have a better effect if a player wants to maintain a high level of play throughout the season.

Furthermore, the article "What Is 'Load Management' and Why Does it Matter for Athletes?" states that load management starts with calculating workload. Although the majority of athletes and coaches do not have sophisticated equipment to measure biomarkers associated with fatigue and global positioning systems to accurately monitor running distance, acceleration, and vertical or horizontal displacement throughout practices and games, stress can still be quantified utilizing a rating of perceived exertion (RPE) scale, a valuable tool to measure the intensity of physical activity. The scale runs from 1 through 10, with 10 defined as maximal exertion, meaning one cannot push any harder [3].

The calculation of the RPE gives a good visualization of the physical effort and energy expended by the athletes during their training. This value indicates whether the athlete should increase or decrease the amount of training for the day. In addition to training, the athlete's load during the competition is also crucial. Playing time and attendance are very good criteria for determining this, as they give us a good idea of the amount of pressure the player is under throughout the season.

The article "Load Management for Lifetime Athletes: gives one example of the consequences of mismanagement: the Overuse Injury. This can be a foot or shin pain or any "itis" represented by sores or inflamed tissues. Even stress fractures can fall into this category. The athlete keeps applying loading cycles that are too high or too frequent for a given tissue to tolerate and adapt to. They go over the limit, and the tissue breaks down. This is often seen in the case of motivation misapplied [4].

These are common mistakes in our load management and usually, happen when athletes and their coaches need to pay attention to reasonable load management. Consequently, the athlete's body will enter a more fatigued state, thus contributing to worsening the existing condition and greatly increasing the risk of injury.

2 Methods

2.1 Data Orientation

The data consists of three main sections corresponding to three sports: minutes played by basketball players of different teams and positions in the NBA, minutes played by players of different positions in hockey and games completed in a season by players in tennis. The data is collected from the public database for NBA, hockey and tennis.

2.2 Mathematical Background

2.2.1 T-test

A t-test is an inferential statistic used to determine if there is a significant difference between the means of two groups and how they are related [5].

Calculating a t-test requires three fundamental data values. They include the difference between the mean values from each data set, the standard deviation of each group, and the number of data values of each group.

In this analysis, we mainly used the Unequal Variance t-test, an independent t-test used when the number of samples in each group is different and the variance of the two data sets is also different.

The formula used for calculating the t-value and degrees of freedom for an unequal variance t-test is presented below:

$$\mathrm{T-VALUE} = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\left(\frac{\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2}{{n_1}^2} + \frac{\sum_{x=1}^{n_2}(x_i-\overline{x_2})^2}{{n_2}^2}\right)}} \ldots \quad (1)$$

where,

$\overline{x_1}, \overline{x_2}$ is the average value(mean) of each of the sample sets.
$\frac{\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2}{n_1}, \frac{\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2}{n_2}$ is the variance of each of the sample sets.
n_1 and n_2 represents number of records in each sample set

$$\text{Degrees of Freedom} = \frac{\left\{\frac{\left[\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2\right]^2}{{n_1}^2} + \frac{\left[\sum_{x=1}^{n_2}(x_i-\overline{x_2})^2\right]^2}{{n_2}^2}\right\}^2}{\frac{\left\{\frac{\left[\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2\right]^2}{{n_1}^2}\right\}^2}{n_1-1} + \frac{\left\{\frac{\left[\sum_{x=1}^{n_2}(x_i-\overline{x_2})^2\right]^2}{{n_2}^2}\right\}^2}{n_2-1}} \ldots \quad (2)$$

Where,

$\frac{\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2}{n_1}, \frac{\sum_{x=1}^{n_1}(x_i-\overline{x_1})^2}{n_2}$ is the variance of each of the sample sets.
n_1 and n_2 represents number of records in each sample set.

2.2.2 ANOVA-Test

Analysis of variance (ANOVA) is a statistical tool that splits an observed aggregate variability found inside a data set into two parts: systematic factors and random factors. The ANOVA test allows a comparison of more than two groups simultaneously to determine whether a relationship exists between them [6].

The general formula used for calculating F-value is presented below:

$$\mathrm{F} = \frac{MST}{MSE} \ldots \quad (3)$$

where,

$$\mathrm{MST} = \frac{\sum_{i=1}^{k}\left(\frac{T_i{}^2}{n_i}\right) - \frac{G^2}{n}}{k-1}\ldots \quad (4)$$

$$\mathrm{MSE} = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n_i=1} Y_{ij}{}^2 - \sum_{i=1}^{k}\left(\frac{T_i{}^2}{n_i}\right)}{n-k}\ldots \quad (5)$$

Hence,

$$\mathrm{F-VALUE} = \frac{n-k}{k-1} \times \frac{\left[\sum_{i=1}^{k}\left(\frac{T_i{}^2}{n_i}\right) - \frac{G^2}{n}\right]}{\left[\sum_{i=1}^{k}\sum_{j=1}^{n_i=1} Y_{ij}{}^2 - \sum_{i=1}^{k}\left(\frac{T_i{}^2}{n_i}\right)\right]}\ldots \quad (6)$$

where,

F is the variance ratio for the overall test.
MST is the mean square due to treatments/groups (between groups).
MSE is the mean square due to error (within groups, residual mean square).
Y_{ij} is an observation.
T_i is a group total.
G is the grand total of all observations.
n_i is the number in group i and n is the total number of observations [7].

2.3 Test Methods

To analyze the physical load of players in different positions in the same sport, we set the position of the players in basketball and hockey as the independent variable and the playing time of the players as the dependent variable. The team conducted ANOVA tests on the position and playing time of the players. Additionally, to analyze the specific differences in physical load on players at different positions in the same sport, the team conducted several T-tests on each of the two positions and the players' playing time. In the T-test, the players' positions are set to be independent variables and the playing time is set to be the dependent variable. Moreover, the team conducted descriptive statistics for the basketball, tennis and hockey datasets to visualize the data better and created graphs around the mean, median, standard deviation, maximum and minimum values.

3 Results

The team first conducted an ANOVA test on the relationship between the position and playing time of players in hockey. After testing, the team found that the F-value in the ANOVA test is much less than 0.5. Therefore, the team concluded that the playing time of different player positions varies significantly.

Field hockey has five player positions: center, left winger, right winger, defender and goalkeeper. The duration of a field hockey game is 60 min, and it is observed that the average playing time of players in positions other than the goalkeeper is around 20 min or less, and the average playing time of the goalkeeper is up to 55 min.

To find out which of the two-player positions had a significant difference in playing time, the team conducted several paired sample T-tests for each of the two positions. Figure 1 has been made according to Hockey, which shows significant differences in playing time between the position of a goalkeeper and every other position [8]. However, there is no difference in playing time among positions besides goalkeeper. As shown in Fig. 1, it presents the average playing time of each position.

The team calculated the standard deviation of playing time for each player position to find the difference in playing time within the same player position. After processing the data, the team further calculated the coefficient of variance. Figure 2 show that the coefficient of variation (Cu = σμ, Careers to the coefficient of variance, σ refers to the standard deviation of the sample set, μ refers to the average value of the sample set). Figure 2 show that the coefficient of variance of Goalkeeper, Center and Defender is below 15%, which is considered normal. However, the coefficient of variance of wingers is slightly above 15%. The reason causing this phenomenon is that the physical load of wingers tends to be greater, and their average playing time is the shortest, at only 15 min, which also leads to the need for the team to frequently change players on the field. The players' physical ability and the game's intensity are uncontrollable factors, so the fluctuation of their playing time is relatively large.

In summary, the very short playing time and frequent substitutions together lead to a slightly higher than the normal coefficient of variance for players. In Fig. 2, the relationship between the coefficient of variance and player positions is presented.

In addition to calculating standard deviations and averages, the group also counted the maximum and minimum values of playing time for each player position. As shown

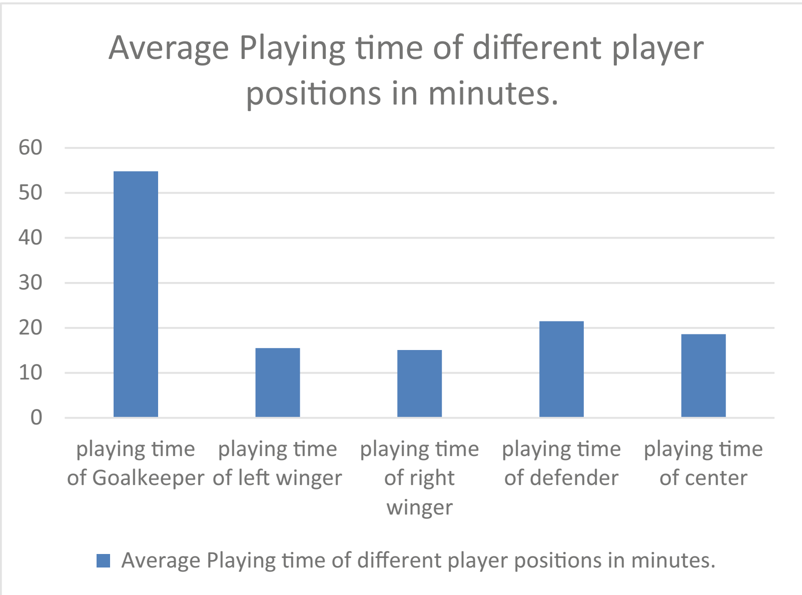

Fig. 1. The average playing time of different player position in minutes [Owner-draw].

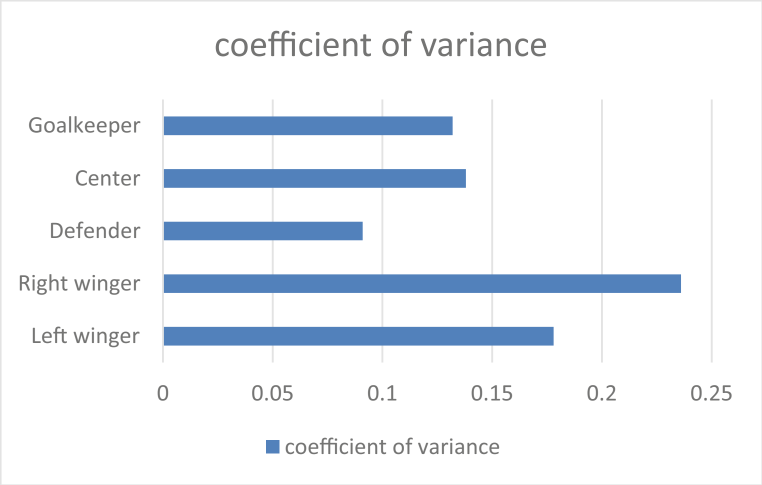

Fig. 2. The relationship between coefficient of variance and player positions [Owner-draw].

in Fig. 3, the relationship between player positions and both the maximum and minimum of playing time is presented in Fig. 3.

Figure 3 shows that the difference between the maximum playing time and the minimum playing time is relatively large, which also testifies to why the winger's coefficient value is above 15% [8]. After analyzing the data related to hockey, the group also analyzed the relationship between player playing time and player position in basketball. The group first conducted an ANOVA test on the entire data set, and Fig. 4 shows no significant difference in the playing time of different player positions in basketball [9]. As shown in Fig. 4, the average playing time of each player's position is presented in Fig. 4.

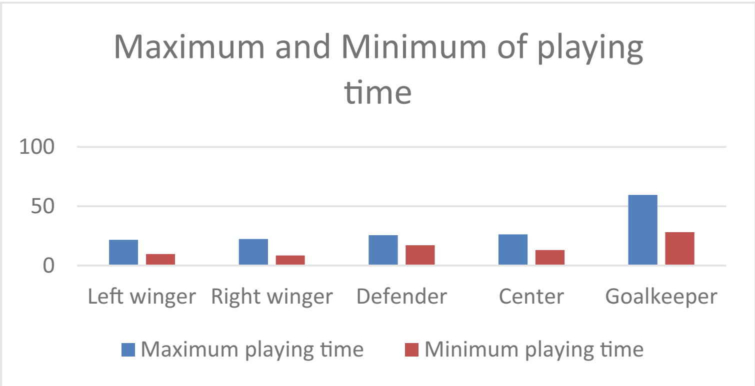

Fig. 3. The maximum and minimum playing time of different player positions in minutes [Owner-draw].

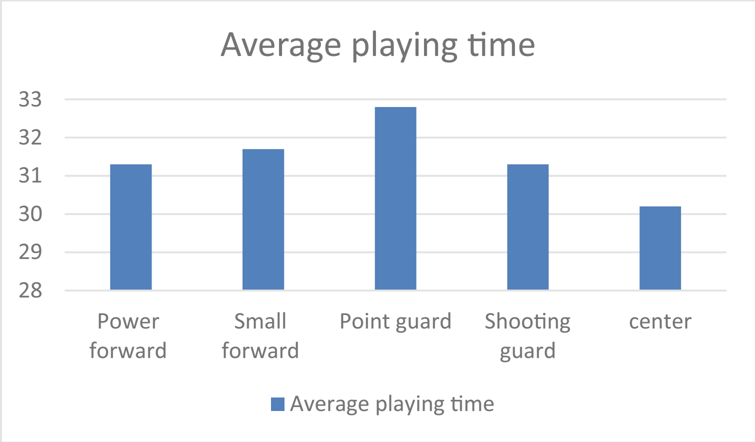

Fig. 4. The average playing time of different player position in minutes [Owner-draw].

Unlike hockey, the average playing time of players in basketball was found to be surprisingly consistent through observation, all being in the 30–35 min range. After analyzing the fundamental nature of the two sports, the group came up with two reasons for this huge difference: In basketball, more emphasis is placed on the interplay between players and the level of understanding between players. Therefore, when coaches make personnel adjustments, they often replace several players at the same time and then put on a new lineup that can play with each other, which is why in basketball, the playing time of players in different positions is nearly the same, while in hockey, more attention is paid to the functionality of a single player position. For example, guards focus on defence, and wingers focus on scoring. Hence, hockey coaches tend to adopt a "one up, one down" strategy when making player adjustments, which explains the large difference in playing time between different positions.

In addition, in basketball, the intensity and physical load of the player is relatively even for the different positions; however, in hockey, the distance and physical exertion of the different positions varies greatly. For example, the range of movement of defenders is smaller than that of wingers, so naturally, defenders tend to play longer on the field. The difference in intensity of movement is the second reason for this huge difference.

Both basketball and hockey are team sports that rely on the interplay between team players to achieve victory. In addition to analyzing team sports, the team also chose tennis as an individual sport to analyze. The total number of games completed by an individual player over a season was chosen as an indicator of the physical load of the player. After statistical analysis of the data, the team found that in tennis, the number of games completed over a season was almost the same from player to player, with a coefficient of variance of only 2.3%, much less than 15%. This shows that the physical load in tennis is relatively consistent from player to the player across the season.

4 Conclusion

The primary result we came up with is that in basketball, an athlete's position on the court does not affect their playing time per game, nor does it affect their attendance throughout the season. Using the above calculation, we conclude that there is no significant difference in the average minutes played in a game between players of different positions. Such a result proves that in basketball, it takes five people with different abilities to form a team and complete the duties in the game well.

The other data shows a certain specificity in the sport of hockey. These data indicate that goalkeepers in hockey have a much higher average playing time than those in all other positions. In the rest of the positions, there is no significant difference in the load received by the players. Therefore, we can assume that the position of the hockey player does not affect their playing time and the pressure they are under, except for the goalkeepers.

Tennis is an individual sport, and the number of rounds and games played by each player is not as different as in a team sport, with differing playing times due to differences in position on the court.

Our data show that basketball players at different positions have similar average minutes played, including similar variance. In our stats, we have more basketball players statistically from guard players, followed by forward players, and the least statistically from the center. This is very similar to our expectations because in today's NBA, more players choose to solve problems from the three-point line, and the center's position in the league is declining. So of the few players, we counted who played the most minutes for each team, the least number of centers were among them. This also suggests that more and more teams may need a center on the court. Of course, this is only our guess. The next data analysis and the specific algorithm will be able to verify our conjecture.

However, the final results did not meet our expectations. The data shows that more than the average number of minutes played by these counted centers are needed to prove our point. The difference between his statistics and those of other positions is too small. Although it is indeed the smallest value, the average of all five positions is very similar, as there is no significant difference between these data.

This also leads us to discuss the conclusion that maybe more centers in the league can't reap the benefits of their former status. Still, different positions in basketball do not affect a player's playing time. It may be because, in basketball, athletes in different positions need to play their respective roles to become a better team.

When analyzing the data for hockey, we predict that it will show the same as basketball, where the position on the field does not make a huge difference in the player's playing time. Even players in different positions should have similar playing times. But when we finished counting all the data, we found that the data showed a partial discrepancy with our expectations. Goalkeepers in hockey play far more minutes than players in other positions. But his playing time is only representative of some of his pressure analysis because of the specificity of his position that the physical load he is subjected to on the field is not reflected by time. More often than not, he stays in front of the goal. Thus, we decided to put the data of goalkeepers as an exception.

When we exclude the goalkeeper position, there is not this much difference in average minutes played by hockey players in other positions, which is more in line with our expectations. We can conclude from the comparison of the data that defensemen do get more ice time. Still, this difference in values is not enough to prove that there is necessarily a large load difference between positions, so we infer that in team sports, after excluding players in certain positions, even if there is a slight difference in ice time between players in different positions, it is not a decisive factor in their load.

In the future or subsequent studies, more data may be available. The NHL (National Hockey League) has kept statistics since its inception and has done so for over a century [10]. In today's high-tech era, it is the trend to use data and technology to help teams win games. After all, the physical stress an athlete is subjected to can be very visualized. But we ignore the athletes' psychological stress; they may be abused by the supporters, suppressed by the head coach, and their family relationships can be, for example, factors we need to consider. These topics are not reflected in the studies we have done so far. A better indicator of load management can be obtained by combining the psychological and physical stresses of the athletes.

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