

KEY GAME-RELATED STATISTICAL PARAMETERS PREDICTING PERFORMANCE INDEX RATING FOR U16, U18, AND U20 BASKETBALL PLAYERS IN DIFFERENT PLAYING POSITIONS

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Abstract: The aim of this study was to determine which game-related statistical parameters could be used to predict the performance index rating of U16, U18, and U20 basketball players in different playing positions. A total of 167 games (box scores for 1813 players) of the finalists teams were analyzed at the FIBA Youth European Championships for men held from 2017-2022 across age categories: U16 (55 games, 595 players), U18 (56 games, 618 players) and U20 (56 games, 600 players). The game-related statistical parameters gathered as independent variables included: total points scored, free throw, 2 and 3-points attempts and made, rebounds, assists, steals, turnovers, personal fouls and blocks. The dependent variable was the Performance Index Rating. The basic descriptive statistics were calculated, while the models of dependency among the observed variables were defined using multiple regression analysis (backward method) at the significance level of $p \leq 0.05$. For players in outside positions, total points scored, assists, steals and offensive and defensive rebounds have a positive impact on their performance index rating. A number of 2-point and free throw attempts, turnovers, 3-point attempts, blocks against and personal fouls committed, have a negative impact. For players in inside positions, positive impact have a number of made 2 and 3-point shots, as well as assists, steals, defensive rebounds and blocks in favour. The negative impact included a 2-point shot attempts, turnovers, and personal fouls committed. These results can help coaches design more effective training programs, to prioritize offensive and defensive skills that positively impact a player's performance.

Keywords: basketball, quantitative indicators, national teams, youth, performance analyses.

INTRODUCTION

In recent years, the integration of advanced quantitative analysis in basketball has significantly transformed how teams evaluate performance and develop strategic approaches. A critical aspect of this transformation is the use of game-related statistics, which provide insights into player and team performance metrics. These statistics are important for understanding the game. The Performance Index Rating (PIR) is one of the primary metrics utilized in basketball analytics during official games (Sansone et al., 2021). It is a mathematical model used by the International Basketball Federation (FIBA) to quantify individual player performance, incorporating various commonly used performance indicators, enabling the comparison of players and teams. This also allows the analysis of how individual characteristics and contextual factors influence game outcomes (Brown et al., 2023).

Research on game-related statistics provides valuable insights into various contexts, such as winning versus losing teams (Gomez et al., 2020) in regular competitions (Cabarkapa, 2024) or major tournaments (Petreanu & Petreanu, 2016), seasonal performance trends ((Zhang et al., 2019; García et al., 2022) and strategic plays (Gómez et al., 2010). This information can enhance understanding of the sport and help coaches and players optimize their performance.

Analyzing individual game-related statistics in youth basketball players is crucial for understanding their performance development and identifying areas for improvement, especially in the context of their specific playing roles – playing positions. This quantitative approach to performance analysis allows coaches to tailor training and development strategies to individual players based on their specific strengths and weaknesses. Research indicates that several factors significantly influence PIR in youth basketball players, including biological maturation, training experience, anthropometric characteristics, physical fitness and playing positions. Older players tend to perform better in basketball due to biological maturation. Studies have shown that more mature players in youth categories demonstrate advantages in skills, decision-making, and overall performance metrics like PIR (Arrieta et al., 2015; Ibáñez et al.,

2018)). This suggests age and maturity are positively correlated with basketball success. Accumulated practice experience also is a strong predictor of performance in youth players, indicating that training hours enhance skill development and game understanding (Ramos et al., 2021; Carvalho et al., 2019; Carvalho et al., 2013). Anthropometric characteristics, such as height and body composition, are linked to basketball performance. Studies have found that physical attributes are critical for success in the sport, with changes in young players' anthropometric structures correlating with athletic performance (Canli et al., 2021). Additionally, body composition has been shown to influence match performance and enhance competitive outcomes as reflected in PIR (Zarić et al., 2020). Additionally, physical fitness, including aerobic fitness and strength, significantly impacts performance in youth basketball (Carvalho et al., 2013). Studies have shown these factors are crucial predictors of success, with point guards often exhibiting higher fitness levels than centers. This allows them to sustain a greater intensity throughout games, leading to more effective scoring and assists, which further enhances their PIR (Milanović et al., 2019). Deliberate training and tactical development can enhance basketball performance metrics, like PIR, by fostering essential cognitive and motor skills. Player positions also influence their respective performance outcomes, with inside players excelling in rebounding and scoring (García-Gil et al., 2018), and outside players contributing significantly through assists and playmaking (Zhai et al., 2021). Understanding these differences is crucial for coaches and analysts in developing strategies that maximize each player's strengths and enhance overall team performance.

The application of regression models has become increasingly prevalent in recent research on analyzing game-related statistics in basketball. These models help to highlight the importance of quantitative analysis in understanding individual and team performance during basketball matches (Simović et al., 2019), as well as predicting scoring trends (Zheng, Ma & Jia, 2023) and identifying key performance indicators that differentiate winning teams from losing ones (Madarambe, 2018). The evaluation of individual and team performance represents a crucial component for basketball coaches in the modern game. Determining the factors that can augment the effectiveness of player performance across different positions, and contribute to achieving victory, is a vital consideration for all basketball teams. Therefore, the purpose of this study was to determine which game-related statistical parameters could be used to predict the performance index rating of U16, U18, and U20 basketball players in different playing positions, identifying both positive and negative impacts.

METHODS

Sample

A total of 167 games (box scores for 1813 players) were analyzed from the FIBA Youth European Championships for men held in period from 2017-2022 across three different age categories: U20 category (56 games, $n = 600$): 2017 – Greece (14 games), 2018 – Germany (14 games), 2019 – Israel (14 games) and 2022 – Montenegro (14 games); U18 category (56 games, $n = 618$): 2017 – Slovakia (14 games), 2018 – Latvia (14 games), 2019 – Greece (14 games) and 2022 – Serbia (14 games) and U16 category (55 games, $n = 595$): 2017 – Montenegro (14 games), 2018 – Serbia (14 games), 2019 – Italy (14 games) and 2022 – Macedonia (13 games).

Box scores of players of the finalists teams (group and final stage) of the named competitions were analyzed. Data were selected from the official FIBA boxscores (www.fiba.com). Game-related statistics data for players who participated in the game for at least five minutes were included in the analysis. The players were divided into two groups: outside (perimeter) players positions (point guard, shooting guard and small forward) and inside (post) players positions (power forward and center) (Wooten, 1992).

Variables

The dependent variable was the Performance index rating. The other examined variables consisted of 16 independent variables, derived from standard individual indicators of game-related statistical parameters. The game-related statistics included: PTS - total points made; FTA - a number of free throw attempts; FTM - a number of made free throws; 2FGA - a number of 2-points attempts; 2FGM - a number of made 2-points shoot; 3FGA - a number of 3-points attempts; 3FGM - a number of made 3-points shoot; ROFF - offensive rebounds; RDEF - defensive rebounds; RTOT - total rebounds; AST - assists; STL - steals; TO - turnovers; PF - personal fouls committed, BLOCF – block in favour and BLOCA – block against.

Statistical analysis

The basic parameters of descriptive statistics (Mean and Standard deviation) were calculated for all variables. The models of dependency in the observed variables (Performance index rating and indicators of game – related statistical parameters) were defined using the multiple regression analysis (backward method). All the statistical operations were performed using software SPSS 24.0. (Chicago, IL, USA) and the level of significance was set at $p \leq 0,05$.

RESULTS

Tables 1-6 present the results of Multiple Regression Analyses examining the association between Performance index rating and game-related statistical parameters for different age categories and playing positions.

Table 1. Backward method Multiple – Regresion analyses of the association of PIR with significant predictor variables for U16 Players in outside positions (n=364)

Variables	Unstd.Beta	Beta	t	p
AST	1.79	0.27	5.62	0.00
PTS	1.37	0.79	8.34	0.00
STL	1.17	0.13	2.63	0.00
RDEF	0.94	0.16	3.18	0.00
2FGA	-1.67	-0.46	-6.49	0.00
3FGA	-1.37	-0.31	-5.08	0.00
TO	-1.35	-0.16	-3.31	0.00
FTA	-1.02	-0.18	-3.15	0.00
PF	-0.71	-0.08	-1.85	0.05
R=0.54	R²_{adjust} = 0.27	Std.Err.Est =9.71	F = 16.49	P = 0.00

Unstd.Beta = Unstandardized regression coefficients values, **Beta** = Standardized regression coefficients values, **t** = Standardized regression coefficients significance test, **p** = Standardized regression coefficients level of significance, **R** = Multiple correlation coefficient, **R²adjust** = Adjusted determination coefficient, **Std. Err. Est.** = Standard error of the estimate, **F** = Multiple regression analysis significance tests, **P** = Multiple correlation level of significance.

The Performance index rating for U16 players in outside positions can be estimated using the following formula:
PIR = 3.698 + (PTS * 1.372) – (2FGA * 1.676) – (3FGA * 1.371) – (FTM * 1.026) + (RDEF * 0.947) + (AST * 1.790) – (PF * 0.710) – (TO * 1.354) + (STL * 1.172)

The analyses identified nine game-related statistical parameters that predict the Performance Index Rating for U16 players in outside positions. Four of them have a positive impact, while five have a negative impact on PIR.

Table 2. Backward method Multiple – Regresion analyses of the association of PIR with significant predictor variables for U18 Players in outside oositons (n=392)

Variables	Unstd.Beta	Beta	t	p
STL	1.91	0.19	4.09	0.00
ROFF	1.26	0.13	2.83	0.00
PTS	0.92	0.46	7.27	0.00
AST	0.90	0.16	3.42	0.00
RDEF	0.86	0.15	2.95	0.00
BLOCA	-1.70	-0.12	-2.67	0.00
2FGA	-0.96	-0.24	-4.04	0.00
FTA	-0.86	-0.17	-3.27	0.00
R=0.53	R²_{adjust} = 0.26	Std.Err.Est =9.40	F = 18.91	P = 0.00

The Performance index rating for U18 players in outside positions can be estimated using the following formula:

$$\text{PIR} = -0.728 + (\text{PTS} * 0.921) - (2\text{FGA} * 0.962) - (\text{FTA} * 0.862) + (\text{ROFF} * 1.268) + (\text{RDEF} * 0.866) + (\text{AST} * 0.905) + (\text{STL} * 1.911) - (\text{BLOC} * 1.720)$$

The analyses identified eight game-related statistical parameters that predict the Performance Index Rating for U18 players in outside positions. Five of them have a positive impact, while three have a negative impact on PIR.

Table 3. Backward method Multiple – Regression analyses of the association of PIR with significant predictor variables for U20 Players in outside positions (n=370)

Variables	Unstd.Beta	Beta	t	p
STL	2.13	0.18	3.28	0.00
AST	1.57	0.26	5.30	0.00
PTS	1.22	0.57	7.04	0.00
3FGA	-1.58	-0.28	-4.63	0.00
TO	-1.13	-0.12	-2.58	0.01
FTA	-1.06	-0.20	-3.82	0.00
2FGA	-0.83	-0.18	-2.98	0.00
R=0.48	R²_{adjust} = 0.23	Std.Err.Est =10.69	F = 15.91	P = 0.00

The Performance index rating for U20 players in outside positions can be estimated using the following formula:

$$\text{PIR} = 1.174 + (\text{PST} * 1.225) - (2\text{FGA} * 0.837) - (3\text{FGA} * 1.584) - (\text{FTA} * 1.061) + (\text{AST} * 1.570) - (\text{TO} * 1.130) + (\text{STL} * 2.136)$$

The analyses identified seven game-related statistical parameters that predict the Performance Index Rating for U20 players in outside positions. Three of them have a positive impact, while four have a negative impact on PIR.

Table 4. Backward method Multiple – Regression analyses of the association of PIR with significant predictor variables for U16 Players in inside positions (n=204)

Variables	Unstd.Beta	Beta	t	p
2FGM	2.54	0.48	4.24	0.00
AST	2.20	0.24	3.68	0.00
3FGM	2.04	0.13	2.18	0.03
BLOCF	1.58	0.11	1.80	0.07
RDEF	0.59	0.13	1.89	0.07
2FGA	-1.28	-0.37	-3.16	0.00
R=0.52	R²_{adjust} = 0.25	Std.Err.Est =9.90	F = 12.51	P = 0.00

The Performance index rating for U16 players in inside positions can be estimated using the following formula:

$$\text{PIR} = -0.835 + (2\text{FGM} * 2.549) - (2\text{FGA} * 1.282) + (3\text{FGM} * 2.041) + (\text{RDEF} * 0.590) + (\text{AST} * 2.206) + (\text{BLOC} * 1.580)$$

The analyses identified six game-related statistical parameters that predict the Performance Index Rating for U16 players in inside positions. Five of them have a positive impact, while only one has a negative impact on PIR.

Table 5. Backward method Multiple – Regresion analyses of the association of PIR with significant predictor variables for U18 Players in inside positions (n=184)

Variables	Unstd.Beta	Beta	t	p
2FGM	2.24	0.52	3.79	0.00
AST	2.32	0.13	4.14	0.00
3FGM	2.05	0.13	2.14	0.03
BLOCF	1.99	0.16	2.46	0.01
PF	-0.96	-0.11	-1.77	0.07
2FGA	-0.73	-0.28	-2.05	0.04
R=0.53	R²_{adjust} = 0.25	Std.Err.Est =9.29	F = 11.66	P = 0.00

The Performance index rating for U18 players in inside positions can be estimated using the following formula:
PIR = 0.585 + (2FGM * 2.246) – (2FTA * 0.731) + (3FGM * 2.053) + (AST * 2.325) – (PF * 0.960) + (BLOC * 1.993)

The analyses identified six game-related statistical parameters that predict the Performance Index Rating for U18 players in inside positions. Four of them have a positive impact, while two have a negative impact on PIR.

Table 6. Backward method Multiple – Regresion analyses of the association of PIR with significant predictor variables for U20 Players in inside positions (n=201)

Variables	Unstd.Beta	Beta	t	p
STL	3.06	0.22	3.41	0.00
3FGM	1.69	0.12	1.92	0.05
RDEF	1.53	0.16	2.51	0.01
2FGM	1.35	0.25	3.77	0.00
TO	-1.62	-0.16	-2.51	0.01
R=0.46	R²_{adjust} = 0.19	Std.Err.Est =10.08	F = 10.87	P = 0.00

The Performance index rating for U20 players in inside positions can be estimated using the following formula:
PIR = -0.481 + (2FGM * 1.358) + (3FGM * 1.690) + (AST * 1.537) – (TO * 1.621) + (STL * 3.067)

The analyses identified five game-related statistical parameters that predict the Performance Index Rating for U20 players in inside positions. Four of them have a positive impact, while only one has a negative impact on PIR.

DISCUSSION

This study aimed to identify game-related statistical parameters that could be used to predict the performance index rating of U16, U18, and U20 basketball players of the finalists teams in different playing positions, based on analyses of European Championships from 2017 to 2022.

The findings indicate that as basketball players mature, the number of game-related statistics that predict their Performance Index Rating tends to diminish. A greater number of game-related statistical parameters predict the PIR for players in outside positions compared to those in inside positions. Differences in PIR between outside and inside players can be attributed to their distinct roles, physical attributes, and playing styles. The key game-related statistical parameters predicting PIR for U16, U18, and U20 basketball players in outside and inside playing positions were identified. For players in outside and inside positions, the number of game-related statistical parameters predicting PIR is similar across the analyzed age categories. However, in the U20 category for inside positions players, there are fewer game-related statistical predictors of PIR.

As players mature, the number of game-related statistics that predict their PIR decreases. This suggests that playing positions become more clearly defined, with players adopting more specialized offensive and defensive roles

and better understanding the demands of the game. Research shows that older basketball players, such as those in the U20 age group, tend to have better game statistics than their younger counterparts in the U16 and U18 age groups. This is likely due to the increased experience and understanding of the game that comes with age and continued participation (Erčulj et al., 2019). U18 players have been observed to demonstrate better cooperation and assertiveness in team play than U16 players, which is essential for effective teamwork in basketball (Pocius & Malinauskas, 2023). With increased maturity, U20 players demonstrate greater poise under pressure and adaptability to diverse game situations compared to their younger counterparts (Joseph et al., 2021).

Research indicates that outside players spent more time in game and also, have more ball possessions, cover greater distances and engage in higher intensity activities throughout a game, which correlates with their elevated PIR scores (Pojskić et al., 2015), and in this case with greater number of game related statistics parameters predicting PIR. For players in outside positions key predictors of PIR with positive influence were related with total points made, assists and steals, and in some categories rebounds (defensive and offensive), while for players in inside positions were related to 2-point and 3-point shots made, assists, steals, blocks, and defensive rebounds.

Key positive impact game-related statistics for both inside and outside players include shooting efficacy, assists, steals, and defensive rebounds. The shooting efficacy of outside and inside players in basketball suggests to be a critical factor that can significantly influence in individual PIR and a team's success in games. Choi et al. (2015) found that guards, in general, contributed positively to their teams' victories through higher 2-point and 3-point shooting percentages (total points scored), along with more assists and fewer turnovers. This suggests that outside players, who are often tasked with scoring, tend to have a more refined shooting technique and greater shooting volume, which enhances their overall effectiveness on the court (Wang & Zheng, 2022). While outside players typically exhibit higher shooting percentages due to their roles in perimeter shooting, centers and power forwards are often expected to convert a higher percentage of their 2-point shots from closer to the basket. Scoring efficiency is crucial, as it directly impacts a team's overall offensive effectiveness. Traditionally, inside positions were not primarily associated with long-range shooting; however, the modern game requires versatile players, including the ability to shoot effectively from beyond the arc. Research indicates that centers and power forwards, are increasingly required to extend their shooting range, so while centers often focus on shots within the paint, power forwards, have more opportunities to shoot from mid-range and beyond (Wang & Zheng, 2022). The positional differences between outside and inside players impact shooting accuracy, with power forwards generally demonstrating better 3-point shooting and more frequent involvement in perimeter shooting compared to other inside positions (Wang & Zheng, 2022), like this study results shows. Assists, particularly from outside players, are a critical discriminator of winning outcomes in basketball as they demonstrate teamwork and the ability to create scoring chances (Ektirici, 2023). Winning teams consistently had more assists than losing teams, highlighting the importance of collaborative play (Raval & Pagaduan, 2021). Guards, and especially point guards, typically have the primary responsibility of distributing the ball and facilitating offensive plays, which leads to them achieving higher assist numbers due to their role in orchestrating plays and distributing the ball (Zhai et al., 2021). This playmaking ability is crucial for their PIR, as assists are a key component of the rating. This role necessitates a high level of court awareness, decision-making skills, and the ability to execute precise passes under pressure, which are vital for offensive efficiency (Zhai et al., 2020). Experienced players, including guards, tend to achieve higher overall performance ratings, with higher assist numbers (Ibáñez et al., 2018). This suggests that as players mature, their ability to read the game and anticipate teammates' movements improves, leading to more successful assists, and this is in relation with founding of this research. Considering inside players, assists are especially relevant for power forwards, who operate in both the post and perimeter areas, facilitating ball movement and creating opportunities for their teammates. The role of steals by outside players in basketball is a significant factor. Steals represent a crucial defensive metric that reflects a team's ability to disrupt the opponent's offense. When outside players successfully steal the ball, it often leads to fast-break opportunities, which can result in easy scoring chances. Carvalho et al. (2017) highlighted that steals can lead to assists, creating a direct link between defensive actions and offensive success. Zhang et al. (2020) found that steals were effective in differentiating teams in closely contested matches during the FIBA Basketball World Cup. Outside players are typically more agile and quicker than players in other positions, which enhances their ability to generate steals, enabling them to engage in high-intensity defensive actions more frequently than forwards or centers (Bae, 2022). Centers and power forwards, besides their rebounding and scoring contributions, are increasingly involved in defensive plays that

generate steals. While centers and power forwards are traditionally associated with rebounding due to their size and positioning, outside players seem also play a critical role in this aspect of the game. The agility and speed of outside players allow them to effectively contest rebounds, especially in fast-paced games where quick transitions are essential. Both offensive and defensive rebounds are associated with positive match outcomes, emphasizing the importance of rebounding across all positions, including guards (Zhang et al., 2020). Inside players' rebounding ability is a critical statistic. Defensive rebounds distinguish between winning and losing teams (Mikić et al., 2018), especially in European competitions (Madarambe, 2018). Winning teams secure more defensive rebounds, limiting opponents' second-chance scoring and enabling faster offensive transitions. Effective rebounding is essential for maintaining possession and controlling the game's tempo (Canuto & Almeida, 2022). Inside players can effectively block shots due to their height and positioning, allowing them to anticipate opponents' actions and make more defensive plays, such as blocks and rebounds (Ibáñez et al., 2018). Inside players who excel at blocking shots can greatly affect the game's outcome. Their defensive presence can deter opponents from driving to the basket and force them to adjust their shooting strategies. (Ibáñez et al., 2018). Simović et al. (2020) pointed that teams with better blocking, rebounding, and scoring tend to win more games. This is because effective blocking and rebounding can lead to higher field goal percentages for the team.

A detrimental impact on PIR for players in outside positions have: 2-point, 3-point, free throw attempts, turnovers, personal fouls committed and blocks against. Therefore, based on offensive-oriented statistical parameters, it appears that poor shooting efficiency, including shots from within the paint and beyond the arc, along with poor free-throw conversion and inadequate shot selection, as well as imprecise passing and ball-handling skills, have a detrimental impact not only on individual PIR, but also on the overall team performance and outcomes. Excessive personal fouls can indicate poor defensive skills and decision-making. It is notable that free throws and personal fouls emerged as significant factors differentiating winning and losing teams, regardless of game pace (Gómez & Ibáñez, 2017). For inside players, factors that can have a detrimental impact on their PIR include excessive 2-point shot attempts, personal fouls committed, and turnovers. To optimize their performance, these players must focus on improving their shooting decision-making and efficiency, playing effective defense, and minimizing turnovers. Excessive turnovers can lead to lost scoring opportunities and transition points for the opposing team, negatively impacting the overall team outcome (Mikołajec et al., 2013). In summary, inside players must balance their offensive contributions with smart decision-making to maintain possession, capitalize on scoring chances and playing defense.

The study's limitations may include the relatively low probability level (19-27%) and prediction accuracy range (± 9.29 -10.87) of the obtained equations. This could be due to the sample consisting primarily of players from winning teams, and the probability might be higher if the sample included a more diverse range of teams and players.

Analyzing game-related statistics in youth basketball, especially for U16, U18, and U20 players, offers insights into performance factors that distinguish winning and losing teams. Regression models are useful tools for analyzing game statistics and their influence on outcomes. By considering various predictors like specific game stats, researchers can build comprehensive models to better understand success factors in basketball at different levels

CONCLUSION

In conclusion, as players age, the number of game-related statistical parameters that predict Performance Index Rating tends to decrease, indicating that playing positions become more defined, with players taking on more specialized roles in offense and defense. Players in outside positions have more game-related statistical parameters that influence their PIR, compared to players in inside positions. For outside players, the common positive influence on PIR across all age categories are total points scored, assists, and steals, and in some categories, offensive and defensive rebounds. Commonly, a high number of 2-point and free throw attempts, and in some categories turnovers, 3-point attempts, blocks against, and personal fouls committed, have a negative influence on PIR. For inside players, common positive predictors of PIR across age categories include made 2 and 3-point shots, as well as in some categories assists, steals, defensive rebounds, and blocks in favour. The negative impact varied by age group but generally included a 2-point shot attempts, turnovers, and personal fouls committed.

Practical Implications

This finding has practical applications, offering a statistical method based on a sample of finalists from recent European Championships to predict Performance Index Rating for U16, U18, and U20 players in different playing

positions (Table 1-6). The obtained equations allow coaches to calculate the Performance Index Rating of their players by inputting the values of the identified parameters.

These results can help coaches design more effective training programs by providing information about individual player performance. Coaches can use this knowledge to prioritize the development of offensive and defensive skills that positively impact a player's Performance Index Rating, while minimizing those with negative effects. This can contribute to the development of winning team strategies and enhanced individual player effectiveness.

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