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Research Article

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Posted Date: November 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11454166/v1

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Additional Declarations: No competing interests reported.

An empirical study on the impact of the "Four Factors" in basketball on the outcomes of professional basketball games in matchups between strong and weak teams—Empirical evidence based on CBA regular season data

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Abstract

This study aims to examine the relationship between the home-away difference in the four basketball factors and the home team's point differential, as well as the consistency of this relationship across different pre-game matchups involving strong and weak teams. Based on regular-season data from seven seasons of the Chinese Basketball Association (CBA), this study selected games where both teams had completed at least five matches prior to the game as the sample. The data were categorized into three scenarios—home-team advantage, evenly matched, and away-team advantage—based on cumulative pre-game winning percentages. Grouped regression analysis, interaction tests, and robustness analysis were then conducted. The results show that the differences in effective field goal percentage, offensive rebound rate, and free throw rate were all positively correlated with the home team's point differential; while the difference in turnover rates was negatively correlated with it (all $p < 0.01$). The simple correlation between the difference in free-throw rates and point differential was negative; however, after controlling for other game performance factors, it became positively correlated. The positive and negative correlation directions for these four factors remained consistent across all three scenarios and were statistically significant;The direction of the association among the four factors was consistent across the three scenarios; interval estimates of coefficient differences and joint tests did not reveal any statistical evidence that the strength of the association varied across scenarios, with a p-value of 0.805 for the overall joint test.

Keywords: CBA Regular Season; Four Factors of Basketball; Home Team Point Differential; Pre-game Matchup Dynamics; Game Performance Analysis

1 Introduction

The "15th Five-Year Plan for Building a Sports Powerhouse" explicitly calls for accelerating the development of a sports powerhouse, reforming and improving the management system and operational

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mechanisms of competitive sports, strengthening the cultivation of young talent and the research and development of sports technology and equipment, enhancing the overall strength of competitive sports, and promoting the revitalization and development of the “three major ball sports”

(General Administration of Sport of China, 2026). The promulgation of this policy provides a practical policy framework for leveraging competition data analysis to assess basketball performance and match outcomes. As a core component of the “three major ball sports,” basketball enjoys a broad grassroots following and high levels of public attention in China(Zhong et al., 2016). Performance analysis, as a cutting-edge field in sports science and technology innovation, has become a vital tool in basketball training and competition research (Hu et al., 2025).As China’ s premier professional basketball league, the Chinese Basketball Association (CBA) provides game statistics that objectively reflect teams’ offensive and defensive capabilities as well as their competitive performance(Zhou, 2006).Analyzing these game data not only deepens our understanding of the patterns governing professional basketball in China but also provides more targeted scientific evidence to guide professional players’ game strategies and training programs(Lu, 2017).

Basketball is a complex, competitive sport characterized by continuous shifts between offense and defense; the outcome of a game is, in fact, the result of the combined effects of various factors, including shots, rebounds, turnovers, free throws, assists, and transitions between offense and defense(Tománek et al., 2026). Existing research has shown that, due to factors such as individual perspective, emotional stress, or the surrounding environment, even high-level coaches find it difficult to accurately recall information about an entire game(Franks and Miller, 1991). Therefore, how to use objective technical statistics or game data to analyze a team’s performance and guide subsequent training has long been a key area of research in the fields of basketball training and game analysis(Zhang, 2014).

Traditional basketball statistics typically describe a team’s performance through individual metrics such as points, rebounds, assists, turnovers, and steals(Cabarkapa et al., 2024). While these metrics reflect a team’s performance in specific technical aspects, the outcome of a basketball game is fundamentally the result of the combined effects of multiple offensive and defensive elements. Any single statistical metric in basketball has inherent limitations; it can only reflect isolated aspects of a team’s offense and defense during a game and struggles to systematically reveal the comprehensive impact of various game behaviors on the final result(Baghal, 2012). In contrast, the “four factors” of basketball—shooting efficiency, possession control, offensive rebounding, and free throws—provide a more comprehensive research perspective for analyzing team performance and are therefore considered a crucial analytical framework for determining the outcome of basketball games(Conte et al., 2018). However, winning or losing is a binary outcome variable that reflects only the direction of the result and fails to capture the degree of difference between the two teams’ performances(Dmochowski, 2023). Even for the same victory, there are notable differences in a team’s performance between a narrow win and a lopsided victory. Therefore, analyzing game outcomes based on point differential helps to examine the relationship between various performance factors and the win-loss outcome in greater detail(García et al., 2013).At the same time, the relationship between a team’s performance and game outcomes may also be influenced by game context. Teams of varying strengths exhibit differences in technical metrics during games and may display distinct performance characteristics(Zhang et al., 2019).Consequently, exploring the relationship between the “four factors” of basketball and game outcomes solely within a general sample may not fully reveal the role of performance metrics under different contexts. Existing research on basketball games generally classifies teams into strong, mid-tier, and weak teams based on their stage-specific winning percentages(Lu et al., 2022). Building on this approach, this study incorporates the pre-game strength

relative of the two competing teams into the analytical framework, which helps examine differences in the relationship between performance indicators and game outcomes across various contexts.

Existing research has largely relied on single, traditional game statistics—such as points, rebounds, assists, and turnovers—to analyze differences in team performance and factors contributing to victory(Leicht et al., 2017; lu, 2017; Cabarkapa et al., 2024),while studies analyzing professional basketball game outcomes using the comprehensive "Four Factors" metric system remain relatively limited. Second, while existing studies have largely used game wins and losses as outcome variables(Gómez et al., 2008; Leicht et al., 2017),these variables only reflect the direction of the game's outcome and fail to clearly reveal the relationship between different technical performances and the margin of victory. Measuring game outcomes using point differential, however, facilitates a more detailed analysis of how various performance factors influence differences in game outcomes. Furthermore, existing research has primarily focused on comparing technical performance between teams of different strengths or treating team strength as a contextual factor influencing game performance(Qiu et al., 2024),while few studies have examined whether pre-game strength disparities between teams affect the relationship between the "Four Factors" of basketball and game outcomes.

Building on the shortcomings of existing research, this study uses the home team's point differential as the dependent variable and the difference in the "four factors" of basketball between the home and away teams as the core explanatory variable. It incorporates the pre-game strength disparity between teams into the analytical framework to compare differences in the relationship between various performance indicators and match outcomes for teams of varying pre-game strength levels when they face off. Simultaneously, it explores the stability and variability of the relationship between the "four factors" of basketball and match outcomes under different pre-game strength disparity scenarios. Through the above analysis, this study builds upon existing research to further deepen our understanding of the relationship between competitive performance and game outcomes in high-level basketball competitions—such as the CBA—as well as the contextual characteristics of this relationship.

2 Theoretical Analysis and Research Hypotheses

2.1 Effective Field Goal Percentage and Home Team Net Points

Effective field goal percentage is one of the key factors determining the outcome of a game; it primarily reflects a team's ability to convert shooting opportunities into points in basketball. Therefore, improving shooting technique is crucial for enhancing athletes' competitive performance(Xu et al., 2012).Effective field goal percentage is calculated by factoring in the additional point value of three-pointers on top of the standard field goal percentage; thus, it reflects the scoring contributions of both two-point and three-point shots(Kubatko et al., 2007).Under conditions where shooting opportunities are comparable, a higher effective field goal percentage means more points are scored per shot attempt, thereby laying the foundation for a team to build a scoring advantage(Britton and Yerger, 2015). Existing research provides empirical support for this expected relationship. Cabarkapa et al. (2022), after analyzing NBA regular-season and playoff games, found that field goal percentage is a key indicator distinguishing winning from losing teams, and that shooting efficiency is a significant explanatory factor in both phases of the season. Their study included 34 NBA Game 7s and found that effective field goal percentage has a consistent positive impact on a team's final point differential(Li et al., 2026). This suggests that shooting efficiency reflects not only the quality of a team's offensive execution but is also related to the team's point differential. Based on this, this paper proposes the following hypothesis:

H1: The difference in effective field goal percentage has a significant positive impact on the home

team's point differential.

2.2 Turnover Rate and Home Team Net Scoring

For shooting efficiency to translate into team scoring, a team must maintain possession and complete its offensive plays. Turnovers, however, can end the current possession, reducing the team's opportunities to continue organizing plays, taking shots, or earning free throws. Trninić et al. (2002) noted in their analysis of European club playoff games that winning teams typically possess better offensive organization, lower turnover rates, and higher field goal percentages, providing a basis for incorporating possession retention into the analysis of game outcomes. Related studies on professional basketball provide further evidence supporting the expected relationship between turnover rates and the home team's point differential. Teramoto and Cross (2010) found in their study that reducing turnovers is one of the key factors explaining the outcomes of NBA games, particularly during the regular season. Özmen (2016), examining the EuroLeague, analyzed changes in statistical performance relative to opponents and found that when the home team's turnover rate was higher than that of the opponent, the probability of winning decreased. These two studies, approaching the issue from the perspectives of a four-factor framework and relative team performance, respectively, support a negative association between turnover rates and favorable game outcomes. The strength of this negative association may be influenced by the game context. Lorenzo et al. (2010) found that in close U16 games, turnovers and assists were key indicators distinguishing winning from losing teams. Although the contexts of youth and professional competitions differ, these results collectively suggest that preserving offensive opportunities by reducing the turnover rate holds competitive value. Based on the theoretical analysis above, when other aspects of game performance are comparable, a higher turnover rate for the home team corresponds to weaker scoring performance. Therefore, after controlling for effective field goal percentage, offensive rebound rate, free throw rate, and other factors, this study expects a negative association between the difference in turnover rates and the home team's point differential. Based on the above analysis, this study proposes the following hypothesis:

H2: The difference in turnover rates has a significant negative effect on the home team's point differential.

2.3 Offensive Rebound Rate and Home Team Net Points Scored

The offensive rebound rate is the proportion of offensive rebounds a team successfully secures out of the total rebounding opportunities consisting of its own offensive rebounds and the opponent's defensive rebounds. It is calculated by dividing the team's offensive rebounds by the sum of the team's offensive rebounds and the opponent's defensive rebounds (Sampaio et al., 2010b). Compared to the number of offensive rebounds, the offensive rebound rate primarily reflects the proportion of times a team successfully regains possession during rebounding battles, making it easier to compare the rebounding performance of both teams. After securing an offensive rebound, a team can continue to shoot, reorganize its offense, or earn free throws, thereby creating subsequent scoring opportunities. Furthermore, the scoring value of offensive rebounds lies in the utilization of these follow-up opportunities. Research on the EuroLeague has found that offensive plays initiated after an offensive rebound are more efficient than those initiated following a turnover, primarily manifested in higher shooting efficiency and more free-throw opportunities(Csátaljay et al., 2017). Further analysis of shots reveals that shots taken after an offensive rebound are more likely to succeed, and winning teams are more efficient on such shots than losing teams(Suárez Cadenas and Courel Ibáñez, 2017). These findings provide evidence that offensive continuity can translate into actual scoring. Existing research on game outcomes further supports this directional expectation. Sampaio et al. (2010), in their analysis of the U.S. team's games at the Beijing

Olympics, found that the difference in offensive rebound rates between the two teams was significantly positively correlated with net scoring per quarter in both full-game and first-half analyses. Yi et al. (2021), in their analysis of WCBA games, also found that offensive rebounding performance—standardized by possession—exhibited a significant positive relationship with the final point differential in both mean models and certain quantiles. Based on the above analysis, the following hypothesis is proposed:

H3: The difference in offensive rebounding rates has a significant positive effect on the home team's net scoring margin.

2.4 Free-Throw Rate and Home Team Net Points

The free-throw rate primarily reflects a team's free-throw points relative to its total field goal attempts throughout the game; it is calculated using the ratio of free throws made to field goal attempts (FTM/FGA) (Migliorati et al., 2023). This metric is influenced by both the number of free throw opportunities and the team's free throw shooting performance; therefore, it reflects a team's ability to earn free throw opportunities and convert them into points. In basketball games where both teams take a similar number of field goal attempts, a higher free throw rate indicates that the team has actually scored more points from free throws. Consequently, the free throw rate is a key indicator affecting a team's scoring and provides another avenue for building a scoring advantage. Existing research has also provided empirical evidence for the link between free-throw performance and scoring advantage. Komić et al. (2024), in their analysis of women's basketball games from the Olympics, World Cup, and continental tournaments, found that in regression models with point differential as the outcome, the difference in free throws made showed a significant positive association. In a study by Simovic et al. (2019), in their analysis of Asian Cup games, found that the difference in free throws made was included in the point differential model and was positively correlated with the final point differential between the winning and losing teams. These results, based on relative free-throw rate and actual free-throw points, respectively, support the importance of focusing on the scoring contribution of free throws. Furthermore, the game-deciding value of free throws is also evident as the game nears its conclusion. Kozar et al. (1994)analyzed NCAA Division I games and found that free throw points accounted for a higher proportion of total points in the final five minutes than in earlier stages, and that winning teams' free throw points constituted a higher proportion of their total points during this period than those of losing teams. This finding further underscores the value of free throw points in the closing stages of a game. Although the aforementioned studies employed different free-throw metrics, they all support the actual scoring contribution of free-throw rate to net scoring margin and provide evidence for the positive association proposed in this paper. Based on this, this paper proposes the following hypothesis:

H4: The difference in free-throw rate has a significant positive effect on the home team's net scoring margin.

2.5 Consistency in the Direction of the Four-Factor Association Across Pre-Game Strength-Weakness Matchup Scenarios

The above analysis presented expected associations between the four factors—field goal scoring, possession retention, second-chance points, and free throw scoring—and the home team's point differential. However, whether these expectations remain consistent across different pre-game strength-weakness matchup scenarios requires further discussion. Pre-game strength-of-opponent scenarios reflect the relative strength of the two teams prior to the start of the game and serve as an important context for understanding a team's technical performance. Dong et al. (2021) through an analysis of the 2019 FIBA Basketball World Cup, found that relative to considering only the opponent's strength, the relative strength between the two teams was more strongly correlated with most technical

metrics—particularly two-point field goal percentage, assists, and defensive rebounds. This suggests that evaluating a team's performance requires taking into account the strength relationship between the home team and its opponent. Sampaio et al. (2010)categorized teams based on their season winning percentage and found that players on stronger teams performed better in two-point shooting and passing. In their study,Gómez et al.(2015) categorized matchups based on final standings and, after controlling for this variable, found that in the final five minutes of close games, field goal percentage, free throw percentage, and offensive rebound rate were all positively associated with winning, while turnovers were negatively associated with a team's victory. These findings provide relevant evidence for examining the four factors in the context of varying team strengths. Migliorati et al. (2023) defined relative strength as the difference in the teams' cumulative pre-game winning percentages and used this to construct a grouped model of the four factors and the probability of winning. According to the results of their final model, the coefficients for field goal percentage, offensive rebound rate, and free throw rate were all positive across different strength groups, while the coefficient for turnover rate was negative. This indicates that while the magnitudes of the regression coefficients for the four factors vary across different strength groups, their signs remain consistent. Combining the aforementioned theoretical analysis, this paper further anticipates that in CBA games, the direction of the positive or negative relationship between the home-away differences in the four factors and the home team's point differential will also remain consistent across different pre-game strength-versus-weakness matchups. Based on this, the following hypothesis is proposed:

H5: Under different pre-game strength-weakness match-up scenarios, the differences in effective field goal percentage, offensive rebound rate, and free throw rate are all positively correlated with the home team's point differential, while the difference in turnover rate is negatively correlated.

3 Design and Procedures

3.1 Data Sources and Sample Description

This study focuses on the relationship between basketball's "Four Factors" and professional basketball game outcomes under pre-match strength matchup scenarios, with individual games from the Chinese Basketball Association (CBA) regular season serving as the unit of analysis.

Technical statistics and game-level data from the CBA regular season were selected as the re search sample. After excluding seasons disrupted by the COVID-19 pandemic and adjustments to the competition format, a total of 2,960 games across seven seasons were compiled, covering the 2014–2015, 2015–2016, 2016–2017, 2017–2018, 2018–2019, 2023–2024, and 2024–2025 campaig ns.The data is sourced from the official website of the Chinese Basketball Association (CBA) ([ht tps://www.cbaleague.com/data/#/home](https://www.cbaleague.com/data/#/home)); and the official Sin a Sports website ([https://cba.sports.sina.com.cn/cba/stats/playerstats/](https://cba.sports.sina.com.cn/cb a/stats/playerstats/)).

Early in a regular season, teams have completed only a small number of games, meaning their cumulative win rate is highly volatile and sensitive to the result of any single match. To mitigate this bias, the main analytical sample excludes games where either the home or away team had played fewer than 5 matches prior to the fixture (351 games in total). The final sample comprises 2,609 games in which both the home and away teams had each played at least 5 regular season games before the matchup.Specifically, this paper investigates the association between home-away differentials in the four metrics (effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate) and the home team's point margin. Furthermore, by incorporating different pre-match strength matchup scenarios defined by teams'

pre-match cumulative win rates, it evaluates the stability of the relationship between basketball's "Four Factors" and game outcomes across varying pre-match strength contexts.

3.2 Variable Selection and Description

3.2.1 Dependent Variable

According to Henry (2019) point differential is the most widely used advanced statistical metric in team sports, and it is a better predictor of future success than simply winning or losing. Based on this, this paper uses the home team's point differential as the dependent variable to measure the difference in game outcomes between the home and away teams in a single game. The formula is as follows:

$$\text{Margin}_i=\text{Points}_{\text{Home},i}-\text{Points}_{\text{Away},i}$$

Here, $Margin_i$ represents the home team's point differential in the i-th game, $Points_{Home,i}$ represents the home team's final score in the i-th game, and $Points_{Away,i}$ represents the away team's final score in the i-th game. The larger the absolute value of the home team's point differential, the greater the point gap between the home and away teams.

3.2.2 Core Explanatory Variables

According to the study by Kubatko et al. (2007), the "Four Factors" in basketball reflect the key elements of a team's success and represent a breakdown of offensive and defensive efficiency metrics. They primarily consist of four indicators: effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate.

Effective field goal percentage, as referenced in the study by Sarlis and Tjortji (2020), is adjusted by applying an additional weight to three-point field goals—since three-pointers yield a higher scoring return than two-pointers—to reflect the impact of different shot types on scoring efficiency. The formula is as follows:

$$eFG\%=\frac{FGM+0.5\times 3PM}{FGA}$$

In this context, eFG% stands for effective field goal percentage, FGM stands for field goals made, 3PM stands for three-pointers made, and FGA stands for field goal attempts.

Turnovers directly end a team's offensive possession and may create a fast-break opportunity for the opponent; therefore, relying solely on the number of turnovers is prone to being influenced by a team's game pace and the number of offensive opportunities. The formula for calculating the turnover rate in this paper is based on the study by Metulini and Gnecco (2023) which is as follows:

$$TOV\%=\frac{TOV}{FGA+0.44\times FTA+TOV}$$

In this context, TOV% refers to the turnover percentage, TOV refers to the number of turnovers, FTA refers to the number of free throw attempts, and FGA refers to the number of field goal attempts.

The formula for calculating the offensive rebound rate is based on the study by Tománek et al., (2026), which is as follows:

$$ORB\%=\frac{ORB}{ORB+Opponent\ DRB}$$

In this context, ORB% refers to the offensive rebound percentage, ORB refers to the number of offensive rebounds, and Opponent DRB refers to the number of defensive rebounds by the opponent.

This paper focuses on the actual contribution of free throws to the final score; therefore, it uses the ratio of free throws made to total field goal attempts as a metric. The formula for calculating the free throw rate is based on the study by Tománek et al. (2026) and is as follows:

$$FTr=\frac{FTM}{FGA}$$

After calculating the four metrics mentioned above separately for the home and away teams, this paper further constructs the differences in their performance metrics to measure the home team's relative advantage or disadvantage over the away team in each technical performance metric within the same game. Specifically, this paper calculates the differences between the home and away teams' scores on the four metrics mentioned above and uses the resulting differences in field goal percentage, turnover rate, offensive rebound rate, and free throw rate as the core explanatory variables. The formulas for calculating the differences in each core explanatory variable are as follows:

$$eFGDiff_i = eFG\%_{Home,i} - eFG\%_{Away,i}$$

$$TOVDiff_i = TOV\%_{Home,i} - TOV\%_{Away,i}$$

$$ORBDiff_i = ORB\%_{Home,i} - ORB\%_{Away,i}$$

$$FTRDiff_i = FTR\%_{Home,i} - FTR\%_{Away,i}$$

In this context, $eFGDiff_i$ represents the difference in effective field goal percentage for Game i, $TOVDiff_i$ represents the difference in turnover rate for Game i, $ORBDiff_i$ represents the difference in offensive rebound rate for Game i, and $FTRDiff_i$ represents the difference in free throw rate for Game i. The subscript "Home" refers to the home team, and "Away" refers to the visiting team.

3.2.3 Other Variables Related to Competition Performance

According to a study by Zadnik et al. (2026) the number of assists is closely associated with winning a game. Furthermore, Zhang (2014) proposed in his study that the pace of the game has a significant impact on the point differential in different matches. Based on this, this paper further incorporates two game performance variables—the assists-to-field-goals-made ratio (Assists per Field Goal Made, AST/FGM) and game pace—to reflect, respectively, the differences between home and away teams in offensive organization and teamwork, as well as the number of offensive and defensive possessions throughout the game and the speed of transitions between offense and defense.

Since the number of assists increases mechanically with the number of field goals made and the number of offensive opportunities, it is influenced by both game pace and scoring opportunities. To mitigate the impact of variations in field goals made and game pace on the number of assists, this study draws on the research by Uhlmann and Barnes (2014) and uses the ratio of assists to field goals made to normalize team assist performance. The formula for this ratio is:

$$AST/FGM = \frac{AST}{FGM}$$

The formula for calculating the assist-to-field-goal-made ratio is as follows:

$$ASTFGMDiff_i = \left(\frac{AST}{FGM}\right)_{Home,i} - \left(\frac{AST}{FGM}\right)_{Away,i}$$

In this context, $ASTFGMDiff_i$ represents the difference in the assist-to-field-goal-made ratio for the i-th game; the subscript "Home" refers to the home team, and "Away" refers to the visiting team.

In this paper, the pace of the game is measured using the average of the estimated number of offensive possessions by both teams in a single game. Kubatko et al. (2007) argued in their study that using the average of the estimated offensive possessions for both teams yields a result closer to the actual number of possessions in a game than using the estimate for a single team. Therefore, drawing on the simplified method for estimating possessions from their study, this paper first estimates the offensive possessions for the home and away teams in the i-th game based on their respective field goal attempts, free throw attempts, offensive rebounds, and turnovers:

$$POSS_{Home,i} = FGA_{Home,i} + 0.44FTA_{Home,i} - ORB_{Home,i} + TOV_{Home,i}$$

$$POSS_{Away,i} = FGA_{Away,i} + 0.44FTA_{Away,i} - ORB_{Away,i} + TOV_{Away,i}$$

Based on this, the average of the estimated number of offensive possessions for the home and away teams is used as the initial game pace for the i-th game:

$$Pace_i=\frac{Poss_{Home,i}+Poss_{Away,i}}{2}$$

When expanded, it reads:

$$Pace_i=\frac{\left(FGA_{Home,i}+0.44FTA_{Home,i}-ORB_{Home,i}+TOV_{Home,i}\right)+\left(FGA_{Away,i}+0.44FTA_{Away,i}-ORB_{Away,i}+TOV_{Away,i}\right)}{2}$$

In this context, FGA, FTA, ORB, and TOV represent field goal attempts, free throw attempts, offensive rebounds, and turnovers, respectively; the subscript "Home" denotes the home team, and "Away" denotes the visiting team.

Given that some games go into overtime, using the estimated number of offensive possessions for the entire game might mechanically increase the game pace due to the extended duration. To ensure comparability across different games, this paper follows the method for calculating game pace outlined by Ertug and Castellucci (2013), standardizing the average estimated number of offensive possessions for both the home and away teams based on each team's total playing time to a pace per 48 minutes. The calculation formula is as follows:

$$Pace_i=48\times\frac{Poss_{Home,i}+Poss_{Away,i}}{2\times(MP_i/5)}$$

In this context,$Pace_i$ represents the standardized pace of the i-th game per 48 minutes; $Poss_{Home,i}$ and $Poss_{Away,i}$ represent the estimated number of offensive possessions for the home and away teams, respectively; and MP_i represents the total playing time of all players on the team in the i-th game.

3.2.4 Pre-match Match-Up Variables Based on Team Strength

According to the study by Lopez et al., (2018), research on game performance uses the cumulative winning percentage up to the current stage of the season. Additionally, a related study by Gonçalves et al. (2023)categorized teams into strong, mid-tier, and weak teams. Based on this, this paper constructs a pre-game strength-based matchup variable using teams' cumulative pre-game winning percentages from the CBA regular season and, following the methodology in Gasperi et al. (2020), this paper calculates teams' pre-game winning percentages using the following formula:

$$PreWinRate_{i,t}=\frac{Win_{i,t-1}}{Game_{i,t-1}}$$

In this context, $Win_{i,t-1}$ represents the cumulative number of wins for team i prior to the start of game t, and $Game_{i,t-1}$represents the cumulative number of games played by team i prior to the start of game t.

Given that cumulative winning percentages tend to be less stable early in the season when teams have played fewer games, this paper constructs this variable using only a sample of games in which both the home and away teams had played at least five games prior to the match.

Existing research on basketball typically uses a team's winning percentage to measure its strength and distinguishes between teams of different levels based on differences in winning percentage. For example, in their study, Yang et al., (2021) defined teams with a winning percentage of around 60% as strong teams and those with a winning percentage of around 40% as weak teams. Based on this, this paper defines teams with a pre-game cumulative winning percentage of at least 60% as strong teams, teams with a pre-game cumulative winning percentage of no more than 40% as weak teams, and teams with a pre-game cumulative winning percentage greater than 40% but less than 60% as mid-tier teams. We then categorize the pre-game matchups based on the strength classifications of the opposing teams and incorporate these into subsequent empirical models. After aggregation, a total of nine different pre-match match-up scenarios were identified, including:

strong team vs. mid-tier team, strong team vs. weak team, mid-tier team vs. weak team, strong team vs. strong team, mid-tier team vs. mid-tier team, weak team vs. weak team, mid-tier team vs. strong team, weak team vs. strong team, and weak team vs. mid-tier team. Based on these nine pre-match strength combinations, this paper further categorizes them into three pre-match strength scenarios according to the relative strength of the home and away teams: the home team has a relative pre-match strength advantage, both teams are of equal pre-match strength, and the away team has a relative pre-match strength advantage. These categories are used for subsequent grouped regression and interaction term analysis.

3.3 Model Specifications

3.3.1 Baseline Regression Model

To examine the impact of the "four factors" in basketball on the outcomes of CBA regular-season games, this study uses the home team's point differential ($Margin_i$)in the i-th game as the dependent variable. The independent variables are the effective field goal percentage differential ($eFGDiff_i$), the turnover rate differential ($TOVDiff_i$), the offensive rebound rate differential ($ORBDiff_i$), and the free throw rate differential ($FTRDiff_i$). In addition, this study further incorporates the assist-to-field goal ratio difference($ASTFGMDiff_i$)and game pace ($Pace_i$)into the model as additional game performance variables. The model is specified as follows:

$$Margin_i=\alpha+\beta_1 eFGDiff_i+\beta_2 TOVDiff_i+\beta_3 ORBDiff_i+\beta_4 FTRDiff_i+\gamma_1 ASTFGMDiff_i+\gamma_2 Pace_i+\lambda_s+\mu_h+v_a+\varepsilon_i \quad (1)$$

In this model,represents the net point differential for the i-th game, while $eFGDiff_i$、$TOVDiff_i$、$ORBDiff_i$、$FTRDiff_i$represent the effective field goal percentage differential, turnover rate differential, offensive rebound rate differential, and free throw rate differential, respectively; $ASTFGMDiff_i$ denotes the assist-to-field-goal-made ratio difference; $Pace_i$ denotes the game pace; λ_s、μ_h、$v_a$denote the season fixed effect,home team fixed effect, and away team fixed effect, respectively; and ε_i denotes the random error term. In the basic OLS model, λ_s、μ_h、v_a；are not included; whereas in the OLS fixed-effects model, λ_s、μ_h and v_a must be included.

3.3.2 Interaction Term Regression Model

To further examine whether a team's pre-game strength-of-opponent scenario affects the impact of the "four factors" in basketball and other game performance variables on the home team's point differential, this paper introduces interaction terms between the pre-game strength-of-opponent scenario and each game performance variable into the baseline regression model. Using scenarios where both teams are of comparable pre-game strength as the reference group, the following interaction regression model is constructed:

$$Margin_i=\alpha+X_i\beta+\delta_1 HomeStrong_i+\delta_2 AwayStrong_i+(Homestrong_i\times X_i)\theta_1+(AwayStrong_i\times X_i)\theta_2+\lambda_s+\mu_h+v_a+\varepsilon_i \quad (2)$$

Here, $X_i$is the performance vector for the i-th game, comprising the effective field goal difference ($eFGDiff_i$), turnover rate difference ($TOVDiff_i$), offensive rebound rate difference ($ORBDiff_i$), free throw rate difference ($FTRDiff_i$), assist-to-field-goal ratio($ASTFGMDiff_i$), and game pace($Pace_i$)；β、θ_1 *and* θ_2 are the corresponding coefficient vectors; $HomeStrong_i$ indicates that the home team had a relative pre-game strength advantage in the i-th game; $AwayStrong_i$ denotes the relative pre-game strength advantage of the away team in the i-th game, with the scenario where both teams have equal pre-game strength serving as the reference group; $(Homestrong_i\times X_i)\theta_1$ and $(AwayStrong_i\times X_i)\theta_2$ represent the

interaction terms between the pre-game strength advantage/disadvantage and the game performance variables, respectively;λ_s、μ_{h} and v_a represent the season fixed effect, home team fixed effect, and away team fixed effect, respectively, while $\varepsilon_i$is the random error term.

3.4 Statistical Analysis

This study uses individual games as the basic unit of analysis. It matches and organizes the statistical data for home and away teams in the CBA regular season, calculates effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate, and constructs the differences between home and away teams for each metric. Additionally, it calculates the difference in the assist-to-shot ratio and the standardized game pace per 48 minutes to generate analytical data at the game level.

(1)The distribution characteristics of the main variables were described using mean, standard deviation, minimum, maximum, median, and quartiles. Pearson correlation analysis was used to examine the linear relationships among the main variables, and a diagnosis of multicollinearity was conducted. Regarding the relationship between the free-throw rate differential and the home team's net points, the results of simple regression, multiple regression, and partial correlation analysis were further compared to examine changes in the association between the two variables before and after controlling for other game performance variables.

(2)Ordinary least squares (OLS) were used to estimate the relationship between the "four-factor" home-away difference in basketball and the home team's point differential. The model incorporated the difference in the assist-to-field-goal-made ratio and game pace, while further controlling for season, home team, and away team fixed effects. Building on this, regression estimates were conducted separately for three match-up scenarios: when the home team had a relative pre-game strength advantage, when both teams were of equal pre-game strength, and when the away team had a relative pre-game strength advantage. Using the scenario where both teams were of equal pre-game strength as the reference group, interaction terms between the match-up scenario and each game performance variable were introduced to test for differences in the relationship across different scenarios.

(3)To assess whether the relationship between the "four major factors" and the home team's point differential varies depending on different pre-game strength scenarios, this study calculated pairwise coefficient differences and their 95% confidence intervals based on an interaction term regression model. For each factor, three scenarios were compared, resulting in a total of 12 comparisons. Subsequently, the Wald F-test was used to compare the differences in the coefficients for each factor and for all four factors across different scenarios. To address the issue of multiple comparisons, the Holm correction was applied separately to the joint test of the four individual factors and to the 12 pairs of comparisons.

(4)The robustness of the main results was tested by excluding games in which the home team's net scoring margin exceeded 40 points, excluding overtime games, applying robust standard errors based on bidirectional clustering of home and away teams, and replacing the dependent variable with whether the home team won, using a linear probability model for estimation.

4 Results

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics for the main variables. The sample consists of 2,609 CBA regular-season games in which both the home and away teams had played at least five games prior to the match. Specifically, the mean home team point differential was 4.664, indicating that the home team generally held a scoring advantage over the away team, which is consistent with the home-court

advantage commonly observed in basketball. In terms of dispersion, the standard deviation of the home team's point differential is 15.570, with a minimum of -55 and a maximum of 60. This indicates significant variation in the margin of victory across different games, ranging from instances where the home team wins by a large margin to cases where it loses by a large margin. The 25th percentile of the home team's point differential is -7, the median is 6, and the 75th percentile is 15. This indicates that the sample includes both games where the home team was at a disadvantage and games where the home team held a certain advantage, suggesting that the point differential variable exhibits sufficient dispersion. Looking at the core explanatory variables, the mean of the effective field goal percentage difference is 0.014, and the median is 0.016, indicating that the home team's shooting efficiency is slightly higher than that of the away team overall. The minimum value is -0.356, the maximum is 0.363, and the standard deviation is 0.098, suggesting that the gap in shooting efficiency between the two teams fluctuates across different games. The mean of the turnover rate difference is -0.011, and the median is -0.010, indicating that the home team's overall turnover rate is slightly lower than that of the visiting team, reflecting that the home team may have certain advantages in game organization, offensive stability, and on-court adaptability. The mean of the offensive rebound rate difference is 0.015, and the median is 0.017, indicating that the home team generally holds a slight advantage in second-chance opportunities. The mean difference in free throw rate is 0.014, with a median of 0.012, indicating that the home team holds a slight overall advantage in scoring from the free throw line.

Furthermore, the mean difference in the assist-to-field-goal ratio is 0.033, with a median of 0.034—one of the higher mean values among the difference variables—suggesting that the home team performs better overall in offensive coordination and team organization. The mean game pace was 93.079, with a standard deviation of 5.250, a minimum value of 74.220, and a maximum value of 112.680, indicating relatively significant differences in the pace of play across different games.

Overall, the sample data exhibits sufficient dispersion in terms of point differential and vario us match performance metrics, providing a solid data foundation for subsequent analysis of how match performance metrics influence match outcomes in different pre-match strength-versus-weakn ess scenarios.

Table 1: Descriptive Statistics for Key Variables

Variable	N (games)	Mean	SD	Minimum	25th percentile	Median	75th percentile	Maximum
Home-team point differential	2609	4.664	15.570	-55.000	-7.000	6.000	15.000	60.000
Effective field goal percentage differential	2609	0.014	0.098	-0.356	-0.055	0.016	0.081	0.363
Turnover percentage differential	2609	-0.011	0.050	-0.183	-0.044	-0.010	0.023	0.175
Offensive rebound percentage differential	2609	0.015	0.118	-0.510	-0.065	0.017	0.095	0.434
Free-throw rate differential	2609	0.014	0.111	-0.417	-0.058	0.012	0.086	0.454
Assist-to-field-goal-made ratio differential	2609	0.033	0.149	-0.569	-0.065	0.034	0.131	0.692

Game pace	2609	93.079	5.250	74.220	89.480	92.980	96.520	112.680

4.2 Multicollinearity Tests and Correlation Analysis

Prior to conducting the regression analysis, this paper first performed multicollinearity tests on the main explanatory variables. Two models were constructed: Model 1 did not include pre-game matchup scenario variables; Model 2 further incorporated a nine-category matchup scenario variable based on cumulative pre-game winning percentage, in addition to Model 1. Both models used a sample of 2,609 games and controlled for fixed effects of season, home team, and away team. The test results are presented in Table 2-1. The test results for Model 1 show that the GVIF values for the difference in field goal percentage, the difference in turnover rate, the difference in offensive rebound rate, the difference in free throw rate, the difference in assist-to-field-goal-attempt ratio, and game pace ranged from 1.170 to 1.465, all significantly below the commonly used critical value of 5. This indicates that the explanatory variables in the baseline model do not exhibit significant multicollinearity. In Model 2, after incorporating the nine-category pre-game matchup scenario variable, the GVIF values for the six continuous explanatory variables ranged from 1.204 to 1.575, remaining significantly below the commonly used critical value of 5. The adjusted GVIF for the nine-category pre-game matchup scenario variable was 1.142, close to 1, indicating that there is no significant multicollinearity issue and that subsequent regression analysis may proceed.

Table 2-1: VIF Test Results

Variable	Model 1: Without pre-game matchup scenarios				Model 2: With nine-category pre-game matchup scenarios			
	GVIF	df	Adjusted GVIF	Assessment	GVIF	df	Adjusted GVIF	Assessment
Effective field goal percentage differential	1.465	1	1.210	No substantial multicollinearity	1.575	1	1.255	No substantial multicollinearity
Turnover percentage differential	1.223	1	1.106	No substantial multicollinearity	1.279	1	1.131	No substantial multicollinearity
Offensive rebound percentage differential	1.170	1	1.082	No substantial multicollinearity	1.205	1	1.098	No substantial multicollinearity
Free-throw rate differential	1.186	1	1.089	No substantial multicollinearity	1.206	1	1.098	No substantial multicollinearity
Assist-to-field-goal-made ratio differential	1.200	1	1.095	No substantial multicollinearity	1.204	1	1.097	No substantial multicollinearity
Game pace	1.253	1	1.120	No substantial multicollinearity	1.259	1	1.122	No substantial multicollinearity
Pre-game matchup scenario (nine categories)	—	—	—	—	8.336	8	1.142	No substantial multicollinearity

Season fixed effects	Yes	Yes
Home-team fixed effects	Yes	Yes
Away-team fixed effects	Yes	Yes
N (games)	2609	2609

Note: Model 1 does not include pre-match head-to-head variables, while Model 2 includes nine-category pre-match head-to-head variables; both models control for fixed effects of season, home team, and away team.

After ruling out the risk of severe multicollinearity, this study further conducted a Pearson correlation analysis on the main variables; the results are shown in Table 2-2. Among them, the correlation coefficient between the home team's point differential and the difference in effective field goal percentage was 0.811, and it was significant at the 1% level. This indicates that the higher the home team's effective field goal percentage is relative to the visiting team's, the larger their point differential typically is, suggesting a strong positive correlation between the two. The correlation coefficient between the home team's point differential and the difference in turnover rates was -0.267, which was significant at the 1% level. This indicates that the higher the home team's turnover rate relative to the opponent's, the lower the point differential; conversely, a reduction in the home team's turnovers helps widen the scoring lead. The correlation coefficient between the home team's point differential and the difference in offensive rebound rates is 0.421, and it is significant at the 1% level. This indicates that the higher the home team's offensive rebound rate relative to the visiting team, the more likely they are to widen their lead by creating additional second-chance opportunities.

The correlation coefficient between the difference in free throw rate and the home team's point differential is -0.062, and it is significant at the 1% level, indicating a negative correlation between the two. This result differs somewhat from general expectations; the reason for this may be that the relationship between the difference in free throw rate and point differential is influenced by other factors related to game performance. To further explore this finding, this study conducted multiple regression and partial correlation analyses while controlling for factors such as the difference in effective field goal percentage, the difference in turnover rate, the difference in offensive rebound rate, the difference in assist-to-field-goal ratio, game pace, and pre-game matchup conditions. The results were then compared with those of simple regression; the findings are shown in Tables 2–3.

The relationship between the difference in free throw rate and the home team's net scoring margin exhibits a notable difference before and after controlling for other variables. When other game performance indicators were not controlled for, the Pearson correlation coefficient between the difference in free throw rate and the home team's point differential was −0.062, which was significant at the 1% level. The results of the simple regression also showed that the regression coefficient for the difference in free throw rate was −8.680, which was significant at the 1% level. This suggests that, based solely on the uncontrolled univariate relationship, a higher free throw rate differential does not increase as the home team's point differential increases.

However, after controlling for factors such as the difference in effective field goal percentage, the difference in turnover rate, the difference in offensive rebound rate, the difference in assist-to-field-goal

ratio, game pace, and pre-game matchup circumstances, the regression coefficient for the free throw rate difference changed to 21.899 and was significant at the 1% level; The results of the partial correlation analysis similarly show that, after controlling for the aforementioned variables, the partial correlation coefficient between the free throw rate differential and the home team's point differential is 0.557, and is significant at the 1% level. These results indicate that, when other game performance metrics are held constant, a higher free throw rate for the home team relative to the visiting team tends to correspond to a larger home team point differential. Furthermore, the reversal in the estimated direction after controlling for these variables also suggests that there is a certain association between the difference in free throw rates and other game performance indicators; therefore, the relationship between the difference in free throw rates and the net score cannot be judged solely based on its simple correlation coefficient.

Table 2-2 Results of Pearson Correlation Analysis

Variable	Home-team point differential	Effective field goal percentage differential	Turnover percentage differential	Offensive rebound percentage differential	Free-throw rate differential	Assist-to-field-goal-made ratio differential	Game pace
Home-team point differential	1.000						
Effective field goal percentage differential	0.811***	1.000					
Turnover percentage differential	-0.267***	0.150***	1.000				
Offensive rebound percentage differential	0.421***	0.111***	0.029	1.000			
Free-throw rate differential	-0.062***	-0.140***	0.185***	-0.062***	1.000		
Assist-to-field-goal-made ratio differential	0.247***	0.282***	0.014	0.017	-0.020	1.000	
Game pace	0.088***	0.075***	-0.003	0.010	0.014	0.066***	1.000

Note: * indicates significance at the 1% level.**

Table 2-3: Comparison of Control Variables Before and After the Analysis of the Relationship Between the Difference in Free-Throw Rates and the Home Team's Net Scoring Margin

Analysis	Adjusted for other variables	Covariates	Regression or correlation coefficient

Pearson correlation	No	None	-0.062***
Simple regression	No	None	-8.680*** (2.680)
Multiple regression	Yes	Effective field goal percentage differential, turnover percentage differential, offensive rebound percentage differential, assist-to-field-goal-made ratio differential, game pace, and pre-game matchup scenario	21.899*** (0.653)
Partial correlation	Yes	Effective field goal percentage differential, turnover percentage differential, offensive rebound percentage differential, assist-to-field-goal-made ratio differential, game pace, and pre-game matchup scenario	0.557***

Note: * indicates significance at the 1% level. Pearson and partial correlations report correlation coefficients, while simple and multiple regressions report unstandardized regression coefficients; the values in parentheses are HC1 heteroscedasticity-robust standard errors.**

4.3 Benchmark Regression Analysis

Table 3 presents the results of the baseline regression analysis. This study constructed both a basic OLS model and an OLS fixed-effects model. The basic OLS model does not control for fixed effects and is primarily used to examine the overall relationship between various match performance indicators and the home team's goal difference; the OLS fixed-effects model further controls for season fixed effects, home team fixed effects, and away team fixed effects, thereby eliminating the influence of different seasonal environments, home team characteristics, and away team characteristics on the estimation results. The signs and significance levels of the core variables are largely consistent across both models, indicating that the baseline regression results exhibit good stability. Since the fixed-effects model can more effectively control for unobserved heterogeneity, this paper primarily relies on the OLS fixed-effects model for interpretation.

According to the results of the fixed-effects model, the regression coefficient for the effective field goal percentage differential is 134.566 and is significant at the 1% level, indicating that the effective field goal percentage differential has a significant positive impact on the home team's point differential. Since the difference in effective field goal percentage is measured as a ratio, this can be interpreted as follows: holding all other conditions constant, for every 1 percentage point increase in the home team's effective field goal percentage relative to the away team, the home team's point differential increases by an average of approximately 1.345 points. This indicates that shooting efficiency is a key factor influencing the point differential in a game.

The regression coefficient for the difference in turnover rates is -132.172, and it is significant at the 1% level, indicating that the higher the home team's turnover rate relative to the visiting team, the lower its point differential. Specifically, all other things being equal, for every 1 percentage point increase in the home team's turnover rate relative to the visiting team, the home team's point differential decreases by an

average of approximately 1.321 points. These results indicate that turnovers not only reduce a team's offensive opportunities but may also create fast-break opportunities for the opponent; therefore, the ability to control turnovers is a critical factor influencing game outcomes.

The regression coefficient for the difference in offensive rebound rate is 44.998 and is significant at the 1% level, indicating that the higher the home team's offensive rebound rate relative to the visiting team, the greater the home team's net scoring margin. For every 1 percentage point increase in the home team's offensive rebound rate relative to the visiting team, the home team's net scoring margin increases by an average of approximately 0.450 points. This suggests that offensive rebounds help teams extend their offensive possessions and create second-chance opportunities, thereby playing a positive role in widening their scoring lead.

The regression coefficient for the free throw rate differential is 22.154, and it is significant at the 1% level, indicating that, after controlling for other game performance metrics, the higher the home team's free throw rate relative to the visiting team, the greater the home team's point differential. For every 1 percentage point increase in the home team's free throw rate differential, the home team's point differential increases by an average of approximately 0.222 points. According to correlation and partial correlation analyses, the free throw rate differential shows a negative correlation with the home team's net scoring margin in a simple correlation analysis; however, this relationship shifts to a significant positive effect after controlling for effective field goal percentage, turnover rate, offensive rebound rate, assist-to-field goal ratio differential, and game pace. This suggests that the impact of the free throw rate differential on game outcomes is influenced by other performance metrics; after controlling for other factors, a higher contribution from free throw scoring can further increase a team's point differential.

Apart from the "four factors" of basketball, the estimation results for the assist-to-field-goal-made ratio differential and game pace exhibit distinct characteristics. Specifically, the regression coefficient for the assist-to-field-goal-made ratio differential is 0.667, which does not reach the level of significance. This result indicates that, after controlling for team-specific characteristics and other game performance metrics, the assist-to-field-goal-made ratio differential alone has limited independent explanatory power for the home team's point differential. The regression coefficient for game pace was 0.041 and was significant at the 1% level, indicating that a fast game pace may influence the outcome of a game by increasing the number of offensive possessions and enhancing a team's offensive opportunities. However, given that the regression coefficient of 0.041 is relatively small, the actual association between game pace and a team's point differential is relatively limited; therefore, game pace is not a primary determinant of the point differential.

In terms of model fit, the OLS fixed-effects model had a sample size of 2,609, an R^2 of 0.952, an adjusted R^2 of 0.951, a Within R^2 of 0.931, and an RMSE of 3.410, indicating that the model possesses good explanatory power and fits the data well.The fixed-effects model showed that the effective field goal percentage differential, offensive rebound percentage differential, and free-throw rate differential were positively associated with the home-team point differential, whereas the turnover percentage differential was negatively associated with it (all $p < 0.01$). These findings support H1, H2, H3, and H4. The support for H4 concerns the conditional association after adjustment for the other variables in the model.

Table 3: Benchmark Regression Results

Variable	Basic OLS model	OLS model with fixed effects

Effective field goal percentage differential	135.427*** (0.809)	134.566*** (0.903)
Turnover percentage differential	-134.253*** (1.421)	-132.172*** (1.485)
Offensive rebound percentage differential	46.008*** (0.607)	44.998*** (0.649)
Free-throw rate differential	22.456*** (0.643)	22.154*** (0.659)
Assist-to-field-goal-made ratio differential	0.787 (0.475)	0.667 (0.487)
Game pace	0.049*** (0.014)	0.041*** (0.015)
Season fixed effects	No	Yes
Home-team fixed effects	No	Yes
Away-team fixed effects	No	Yes
N (games)	2609	2609
R^2	0.950	0.952
Adjusted R^2	0.950	0.951
Within R^2	-	0.931
RMSE	3.480	3.410

Note: Values in parentheses are HC1 heteroscedasticity-robust standard errors; * indicates significance at the 1% level. Within R^2 represents the proportion of variation within the goal differential group explained by the core explanatory variables after controlling for season, home team, and away team fixed effects.**

4.4 Analysis of Heterogeneity in Pre-Match Matchups Between Strong and Weak Teams

4.4.1 Grouped Regression in Matchups Between Teams of Different Strengths

Building on the benchmark regression model described above, this paper further categorizes pre-match scenarios based on the nature of previous head-to-head matches between the home and away teams into three types: situations where the home team has a relative pre-match advantage, situations where both teams are evenly matched, and situations where the away team has a relative pre-match advantage. Regression estimates are then conducted separately for each category to compare differences in the direction of influence and the magnitude of coefficients for each variable across these different scenarios. Specifically, this paper defines “strong team vs. mid-tier team,” “strong team vs. weak team,” and “mid-tier team vs. weak team” as “home team with a relative pre-match advantage”; “strong team vs. strong team,” “mid-tier team vs. mid-tier team,” and “weak team vs. weak team” as “equal pre-match strength between the two teams”; and “mid-tier team vs. strong team,” “weak team vs. strong team,” and

"weak team vs. mid-tier team" as "away team with a relative pre-match advantage" . Based on this classification, this study conducts regression estimates while controlling for season fixed effects, home team fixed effects, and away team fixed effects. The results of the specific group-specific regressions are shown in Table 4. Judging by the model fit, all three types of group-specific models demonstrate good explanatory power. The R^2 values for the three sets of models are 0.928, 0.935, and 0.943, respectively; the adjusted R^2 values are 0.924, 0.931, and 0.940, respectively; and the Within R^2 values are 0.916, 0.926, and 0.932, respectively. This indicates that, even after controlling for fixed effects, the various match performance indicators still provide a good explanation for variations in the home team's goal differential.

Table 4: Results of Grouped Regression Analysis Under Different Pre-Match Strength Matchup Scenarios

Variable	Pre-game home-team strength advantage	Equal pre-game team strength	Pre-game away-team strength advantage
Effective field goal percentage differential	131.332***	134.133***	135.418***
	(1.833)	(1.544)	(1.529)
Turnover percentage differential	-132.572***	-131.275***	-129.739***
	(2.659)	(2.697)	(2.662)
Offensive rebound percentage differential	43.805***	44.748***	43.960***
	(1.372)	(1.056)	(1.146)
Free-throw rate differential	20.346***	22.192***	22.581***
	(1.318)	(1.141)	(1.055)
Assist-to-field-goal-made ratio differential	0.935	1.953**	-1.195
	(0.798)	(0.863)	(0.872)
Game pace	0.082***	0.016	-0.005
	(0.029)	(0.025)	(0.026)
Season fixed effects	Yes	Yes	Yes
Home-team fixed effects	Yes	Yes	Yes
Away-team fixed effects	Yes	Yes	Yes
N (games)	840	884	885
R^2	0.928	0.935	0.943
Adjusted R^2	0.924	0.931	0.940
Within R^2	0.916	0.926	0.932
RMSE	3.375	3.305	3.273

Note: The values in parentheses are HC1 heteroscedasticity-robust standard errors; *, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.**

Based on the overall regression results, the differences in effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate all maintained a significant impact across the three match-up scenarios mentioned above, and the direction of the coefficients was consistent with that of the baseline regression results. This indicates that the "four factors" in basketball provide a strong and stable explanation for the home team's point differential.

Specifically, the difference in effective field goal percentage was significantly positive at the 1% level in all three scenarios, with regression coefficients of 131.332, 134.133, and 135.418, respectively. This indicates that regardless of whether the home team held a relative advantage, was evenly matched, or was at a disadvantage compared to the visiting team prior to the game, shooting efficiency consistently remained a core factor influencing the home team's point differential.

The difference in turnover rates was significantly negative in all three scenarios, with significance at the 1% level, and regression coefficients of -132.572, -131.275, and -129.739, respectively. This indicates that regardless of the pre-game matchup scenario, an excessively high turnover rate reduces the home team's offensive opportunities and may increase the likelihood of the opponent scoring on fast breaks.

The difference in offensive rebound rate was also significantly positive in all three scenarios, with regression coefficients of 43.805, 44.748, and 43.960, respectively, all significant at the 1% level. These results indicate that offensive rebounds help teams extend their offensive possessions and create second-chance opportunities; therefore, regardless of the pre-game strength balance between the two teams, offensive rebounding ability is a key factor influencing the final point differential.

The difference in free-throw rate also exhibited a significant positive effect in all three scenarios, with regression coefficients of 20.346, 22.192, and 22.581, respectively, all significant at the 1% level. These results indicate that teams with higher free-throw rates tend to have relatively higher home-team point differentials, suggesting a consistent positive relationship between the number of free-throw opportunities and the point differential.

The difference in the assist-to-field-goal ratio exhibits relatively distinct variations across different pre-game strength scenarios. In scenarios where the home team holds the advantage, the regression coefficient for the difference in the assist-to-field-goal ratio is 0.935, though it does not reach the level of significance; in scenarios where both teams were of comparable strength prior to the game, the coefficient was 1.953 and was significant at the 5% level; in scenarios where the visiting team held the advantage, the coefficient was -1.195 and was also not significant. These results indicate that the significant positive relationship between the assist-to-shot ratio difference and the home team's point differential primarily occurs in games where both teams are of comparable strength prior to the game. The reason may be that in situations where the teams are relatively evenly matched, higher-quality offensive organization, better passing coordination, and the ability to create high-quality scoring opportunities are more likely to translate into a scoring advantage; whereas in games where there is a clear disparity in pre-game strength, the assist-to-field-goal-made ratio difference has a relatively limited explanatory power for the point differential.

The regression coefficient for game pace was 0.082 in the pre-game home-team strength-advantage scenario and was statistically significant at the 1% level. The corresponding coefficients in the equal-strength and away-team strength-advantage scenarios were 0.016 and −0.005, respectively, and neither was statistically significant. However, these differences in subgroup significance do not themselves establish statistically significant differences between the coefficients across scenarios. Such

differences are examined using the interaction model. Across the three pre-game relative-strength scenarios, the effective field goal percentage differential, offensive rebound percentage differential, and free-throw rate differential remained positively associated with the home-team point differential, whereas the turnover percentage differential remained negatively associated with it. These findings support H5 regarding the consistency of association directions across scenarios. They do not establish that the coefficient magnitudes are equal across scenarios.

4.4.2 Interaction Term Regression Test

To further determine whether the differences in coefficients across different scenarios in the grouped regression are statistically significant, this study introduces interaction terms between the "strong vs. weak" matchup scenario and various match performance indicators into the fixed-effects baseline regression model, thereby testing whether the pre-match "strong vs. weak" scenario significantly moderates the relationship between these performance indicators and the home team's goal differential. The model uses scenarios where both teams are of equal strength before the match as the reference group and controls for season fixed effects, home team fixed effects, and away team fixed effects. The results of the interaction term regression are shown in Table 5.

Table 5: Regression Results for Interaction Terms in Pre-Match Strong-Weak Matchup Scenarios

Variable	Regression model with interaction terms
Effective field goal percentage differential	134.473***
	(1.505)
Turnover percentage differential	-131.570***
	(2.687)
Offensive rebound percentage differential	44.849***
	(1.018)
Free-throw rate differential	22.408***
	(1.105)
Assist-to-field-goal-made ratio differential	1.878**
	(0.834)
Game pace	0.024
	(0.023)
Pre-game home-team strength advantage	-6.889**
	(3.172)
Pre-game away-team strength advantage	3.885
	(2.995)

Pre-game home-team strength advantage × Effective field goal percentage differential	-2.985
	(2.321)
Pre-game away-team strength advantage × Effective field goal percentage differential	0.906
	(2.085)
Pre-game home-team strength advantage × Turnover percentage differential	-0.895
	(3.666)
Pre-game away-team strength advantage × Turnover percentage differential	1.909
	(3.705)
Pre-game home-team strength advantage × Offensive rebound percentage differential	-0.129
	(1.642)
Pre-game away-team strength advantage × Offensive rebound percentage differential	-0.254
	(1.472)
Pre-game home-team strength advantage × Free-throw rate differential	-1.561
	(1.669)
Pre-game away-team strength advantage × Free-throw rate differential	-0.010
	(1.491)
Pre-game home-team strength advantage × Assist-to-field-goal-made ratio differential	-1.030
	(1.151)
Pre-game away-team strength advantage × Assist-to-field-goal-made ratio differential	-2.673**
	(1.172)
Pre-game home-team strength advantage × Game pace	0.083**
	(0.034)
Pre-game away-team strength advantage × Game pace	-0.042
	(0.032)
Season fixed effects	Yes
Home-team fixed effects	Yes
Away-team fixed effects	Yes
N (games)	2609
R^2	0.953

Adjusted R^2	0.952
Within R^2	0.932
RMSE	3.380

Note: The values in parentheses are HC1 heteroscedasticity-robust standard errors. *, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.**

Based on the results of the main effects, under the reference scenario where both teams are of equal strength prior to the game, the differences in effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate all remain statistically significant at the 1% level, and the direction of the coefficients is consistent with the results of the baseline regression and grouping regression discussed earlier; the difference in the assist-to-field goal ratio is significantly positive at the 5% level, while game pace does not reach statistical significance. This indicates that, in matchups where both teams are evenly matched, the "four factors" of basketball remain important determinants of the home team's point differential, while game pace itself does not directly and significantly affect the point differential.

Looking at the interaction terms, the interaction coefficients for the effective field goal percentage difference in scenarios where the home team has the advantage and the away team has the advantage are -2.985 and 0.906, respectively, neither of which reached statistical significance; the corresponding interaction coefficients for the turnover rate difference are -0.895 and 1.909, respectively, and likewise did not reach statistical significance; the corresponding interaction coefficients for the offensive rebound rate differential were -0.129 and -0.254, and those for the free throw rate differential were -1.561 and -0.010, neither of which reached statistical significance. Therefore, the current sample has not revealed any significant differences in the relationship between effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate and the home team's point differential across the three types of pre-game matchup scenarios. Given that the directions and significance levels of the coefficients for these four indicators were largely consistent across the grouped regression analyses, it can be concluded that the relationship between the "four factors" in basketball and the point differential exhibits good stability across different pre-game matchup scenarios.

The interaction coefficient between the assist-to-field-goal-made ratio difference and the "home team advantage" scenario was -1.030, which did not reach statistical significance, indicating that there was no significant difference in the coefficient of the assist-to-field-goal-made ratio between the "home team advantage" scenario and the "equal-level" scenario. The coefficient of the interaction term between the assist-to-field-goal-made ratio difference and the "away team advantage" scenario is -2.673, which is significant at the 5% level, indicating that the coefficient for this indicator is significantly lower in the "away team advantage" scenario compared to the "equal strength" scenario. This result suggests that the relationship between the assist-to-field-goal-made ratio difference and the home team's point differential may vary to some extent depending on the pre-game matchup scenario.

The coefficient of the interaction term between game pace and the "home team advantage" scenario was 0.083 and was statistically significant at the 5% level, whereas the coefficient of the interaction term between game pace and the "away team advantage" scenario was -0.042 and did not reach statistical significance. This suggests that the relationship between game pace and the home team's point differential may be stronger in scenarios where the home team holds the advantage. the effect of game pace on the home team's goal differential is not consistent; it depends on the pre-match strength dynamics. When the home team holds a relative pre-match advantage, a faster pace may amplify that advantage.

In terms of model fit, the interaction term regression model has an R^2 of 0.953, an adjusted R^2 of

0.952, a Within R^2 of 0.932, and an RMSE of 3.380. Compared with the baseline fixed-effects model, R^2, adjusted R^2, and Within R^2 all increased slightly, while RMSE decreased from 3.410 to 3.380. This indicates that the model fit improved slightly after introducing the interaction term between the pre-match strength of the opposing teams and the match performance indicators.

4.4.3 Interval Estimates and Joint Tests for Coefficient Differences

To further examine whether the association between the "four factors" in basketball and the home team's point differential changes depending on the strength of the pre-game matchup, this study conducted interval estimates and joint tests for coefficient differences across the three scenarios based on the aforementioned interaction term model. The results are shown in Table 6. The 95% confidence intervals for all 12 pairwise coefficient differences included zero, and none of the joint Wald tests for the individual factors reached the 0.05 significance level. The overall joint test result for the 8 scenario-interaction coefficients of the four factors was $F(8, 2542) = 0.567$, $p = 0.805$. After Holm adjustment was applied separately to the four joint tests for individual factors and the 12 pairwise comparisons, all adjusted p values remained above 0.05. Under the sample and model specifications of this study, no statistical evidence was found to suggest that the strength of the association between the four factors and the home team's point differential varies with pre-game match-up strength scenarios.

Table 6. Coefficient differences and joint Wald tests across pre-game strength scenarios

Indicator	H - E	A - E	H - A	Joint Wald F (p)
eFG% differential	-2.985 [-7.537, 1.567]	0.906 [-3.183, 4.995]	-3.892 [-8.440, 0.656]	1.471 (0.230)
TOV% differential	-0.895 [-8.084, 6.294]	1.909 [-5.356, 9.173]	-2.803 [-9.920, 4.314]	0.309 (0.734)
ORB% differential	-0.129 [-3.350, 3.091]	-0.254 [-3.140, 2.631]	0.125 [-3.231, 3.481]	0.015 (0.985)
FTR differential	-1.561 [-4.833, 1.712]	-0.010 [-2.935, 2.914]	-1.550 [-4.755, 1.655]	0.557 (0.573)

Notes: H = home team in a higher pre-game strength category; E = teams in the same category; A = away team in a higher category. The values in parentheses are uncorrected p-values, calculated using the HC1 robust covariance.

4.5 Robustness Tests

4.5.1 Model Robustness Tests

To examine whether the results of the benchmark regression in this paper are influenced by factors such as extreme score differentials, overtime games, standard error estimation methods, and the way match outcomes are measured, this paper conducts robustness tests for each of the four aspects mentioned above while keeping the core explanatory variables and fixed effects constant. First, we excluded matches in which the home team's net score exceeded 40 points in absolute value, thereby reducing the impact of matches with extreme score differentials on the estimation results; second, we excluded all overtime matches to eliminate the interference of unusual match durations on the estimation results; third, we calculated two-way clustered robust standard errors based on the home and away team dimensions to mitigate potential error correlation among different matches involving the same home or away team; Fourth, we replaced the dependent variable (home team point differential) with whether the home team won and estimated the model using a linear probability model. All of the above models controlled for

season fixed effects, home team fixed effects, and away team fixed effects. The specific results of the robustness tests are shown in Table 7.

After excluding games where the absolute value of the home team's point differential exceeded 40 points, the sample size decreased from 2,609 games to 2,581 games. The regression coefficients for the difference in effective field goal percentage, the difference in turnover rate, the difference in offensive rebound rate, and the difference in free throw rate were 133.446, -130.771, 44.654, and 21.840, respectively, and all were significant at the 1% level. The directions of the coefficients for the above variables are all quite similar to those in the baseline regression, indicating that the relationship between the "four factors" of basketball and the home team's point differential is not influenced by a small number of games with extreme point differentials. Additionally, the coefficient for the assist-to-field-goal-made ratio difference did not reach the significance level, while the coefficient for game pace was 0.038 and was significant at the 5% level; the model's R^2 and within R^2 were 0.949 and 0.927, respectively, which are essentially consistent with the baseline model.

After excluding all overtime games, the sample size was 2,504 games. The regression coefficient for the effective field goal percentage differential was 134.740; for the turnover rate differential, it was -132.402; and for the offensive rebound rate differential and free throw rate differential, the coefficients were 45.045 and 22.085, respectively. All four indicators were significant at the 1% level. Compared with the results of the baseline regression, neither the direction nor the magnitude of the coefficients for the core explanatory variables changed significantly, indicating that the change in game duration caused by overtime did not alter the core estimation results. The difference in the assist-to-field-goal ratio did not reach the significance level, while game pace maintained a significant positive effect;

Statistical inferences were re-conducted using robust standard errors based on two-way clustering of home and away teams. The results showed that the differences in effective field goal percentage, turnover rate, offensive rebound rate, and free throw rate all remained significant at the 1% level, indicating that the estimates of the "four factors" in basketball remain stable even after accounting for potential error correlation among different games involving the same home or away team. Game pace was significant at the 5% level, while the difference in the assist-to-field-goal ratio remained insignificant, further illustrating that the explanatory power of the "four factors" of basketball on game outcomes is relatively stable.

Finally, this paper replaces the dependent variable with whether the home team wins and uses a linear probability model for estimation. The results show that the regression coefficients for the effective field goal percentage differential, turnover rate differential, offensive rebound rate differential, and free throw rate differential are 3.330, -2.975, 1.188, and 0.892, respectively, and all are significant at the 1% level; These results indicate that the "four factors" in basketball are not only significantly correlated with the final point differential but also provide a stable explanation for game outcomes. The four robustness tests described above demonstrate that the relationship between the "four factors" and CBA regular-season game outcomes exhibits good robustness.

Table 7: Results of Model Robustness Tests

Variable	Excluding extreme point differentials	Excluding overtime games	Two-way clustered standard errors (home and away teams)	Alternative outcome (LPM)
Effective field goal percentage	133.446***	134.740***	134.566***	3.330***

differential	(0.911)	(0.929)	(1.177)	(0.070)
Turnover percentage differential	-130.771***	-132.402***	-132.172***	-2.975***
	(1.493)	(1.541)	(1.530)	(0.130)
Offensive rebound percentage differential	44.654***	45.045***	44.998***	1.188***
	(0.654)	(0.670)	(0.707)	(0.053)
Free-throw rate differential	21.840***	22.085***	22.154***	0.892***
	(0.667)	(0.686)	(0.445)	(0.058)
Assist-to-field-goal-made ratio differential	0.726	0.590	0.667	-0.022
	(0.492)	(0.508)	(0.516)	(0.042)
Game pace	0.038**	0.044***	0.041**	0.000
	(0.015)	(0.016)	(0.019)	(0.001)
Season fixed effects	Yes	Yes	Yes	Yes
Home-team fixed effects	Yes	Yes	Yes	Yes
Away-team fixed effects	Yes	Yes	Yes	Yes
N (games)	2581	2504	2609	2609
R^2	0.949	0.953	0.952	0.652
Adjusted R^2	0.948	0.952	0.951	0.645
Within R^2	0.927	0.932	0.931	0.537
RMSE	3.377	3.434	3.410	0.285

Note: The values in parentheses in columns 1, 2, and 4 are HC1 heteroscedastic robust standard errors; the values in parentheses in column 3 are two-way clustered standard errors. * and ** indicate significance at the 1% and 5% levels, respectively.**

4.5.2 Robustness Test for Scenario Segmentation

To examine whether the classification of pre-match strength-weakness matchups is influenced by the setting of the winning percentage threshold, this study adjusted the criteria for classifying strong and weak teams: teams with a cumulative pre-match winning percentage of at least 65% were defined as strong teams; those with a winning percentage of no more than 35% were defined as weak teams; and teams with a winning percentage between 35% and 65% were defined as mid-tier teams. Based on this, we reconstructed the three categories of pre-match strength scenarios—"home team has a relative pre-match advantage," "both teams are of equal pre-match strength," and "away team has a relative pre-match advantage"—and conducted fixed-effects group regression analysis. The results are shown in Table 8.

Table 8: Robustness Results for Scenario Classification

Variable	Pre-game home-team strength advantage	Equal pre-game team strength	Pre-game away-team strength advantage
Effective field goal percentage differential	133.778*** (1.763)	132.497*** (1.571)	134.955*** (1.551)
Turnover percentage differential	-133.305*** (2.587)	-130.087*** (2.790)	-128.406*** (2.592)
Offensive rebound percentage differential	43.349*** (1.278)	44.723*** (1.144)	44.723*** (1.120)
Free-throw rate differential	20.126*** (1.282)	23.347*** (1.251)	22.216*** (1.011)
Assist-to-field-goal-made ratio differential	0.662 (0.826)	2.042** (0.881)	-0.679 (0.848)
Game pace	0.071** (0.029)	0.031 (0.026)	0.010 (0.025)
Season fixed effects	Yes	Yes	Yes
Home-team fixed effects	Yes	Yes	Yes
Away-team fixed effects	Yes	Yes	Yes
N (games)	838	872	896
R^2	0.930	0.930	0.943
Adjusted R^2	0.926	0.926	0.940
Within R^2	0.919	0.922	0.932
RMSE	3.330	3.393	3.236

Note: Values in parentheses are heteroscedasticity-robust standard errors; ** and * indicate significance at the 5% and 1% levels, respectively. The fixed-effects model automatically excluded 3 observations with single-field data; the three models collectively included a total of 2,606 fields.**

After adjusting the criteria for pre-game strength classifications, the "four factors" in basketball continued to exhibit the same direction of influence as in the baseline analysis across different matchup scenarios. Specifically, the regression coefficients for the effective field goal percentage differential in the three scenarios—where the home team had a relative pre-game strength advantage, both teams were evenly matched, and the away team had a relative pre-game strength advantage—were 133.778, 132.497, and 134.955, respectively, and all were significantly positive at the 1% level. This indicates that regardless of the pre-game strength relationship between the two teams, improving relative shooting efficiency can

still significantly expand the home team's net point advantage. The regression coefficients for the difference in turnover rates under the aforementioned three scenarios were -133.305, -130.087, and -128.406, respectively, and all were significantly negative at the 1% level. This indicates that a higher turnover rate still has a detrimental effect on the game's outcome. The regression coefficients for the difference in offensive rebound rates were 43.349, 44.723, and 44.723, respectively, and were all significantly positive at the 1% level. This suggests that a team's ability to secure offensive rebounds holds relatively stable value across different pre-game strength-matching scenarios. The regression coefficients for the free-throw rate differential in the three scenarios were 20.126, 23.347, and 22.216, respectively, and all reached the 1% significance level. In contrast, the assist-to-field-goal-made ratio difference and game pace still exhibit some variation across different scenarios: the assist-to-field-goal-made ratio difference reaches the 5% significance level only when both teams are of equal pre-game strength, while game pace reaches the 5% significance level only when the home team holds a relative pre-game strength advantage—results that are largely consistent with those from the baseline analysis.

Based on the model fit results, the R^2 values for the three scenarios mentioned above were 0.930, 0.930, and 0.943, respectively, while the adjusted R^2 values were 0.926, 0.926, and 0.940, and the within R^2 values were 0.919, 0.922, and 0.932, respectively. This indicates that even after adjusting the criteria for classifying teams as strong or weak, each match performance indicator still provides a good explanation for changes in the home team's point differential. Therefore, the conclusions of this study regarding the impact of the "four factors" on the outcomes of professional basketball games do not depend on specific win-rate classification criteria and demonstrate good robustness.

5 Discussion

This study primarily utilized data from 2,609 CBA regular-season games spanning seven seasons to examine whether the relationship between the home-and-away team differences in the four factors of basketball and the home team's point differential varies depending on the teams' relative pre-game strength. By combining relative strength scenarios constructed based on pre-game information with various game performance metrics, the study provides evidence to test whether the association between basketball performance metrics and game outcomes differs across various matchup scenarios.

5.1 The "Four Factors" and Net Points Scored in Games

The positive correlation between the effective field goal percentage differential and net points scored reflects the positive relationship between the efficiency with which shooting opportunities are converted into points and the point differential. In the formula for calculating effective field goal percentage, three-point shots are assigned an additional weight, thereby allowing the metric to simultaneously reflect the scoring value of both two-point and three-point shots (Kubatko et al., 2007). In the fixed-effects model of this study, a 1 percentage point increase in the effective field goal percentage differential corresponds to an average increase of approximately 1.346 points in the home team's point differential. This result is consistent with the findings of Tománek et al.,(2026), who observed a positive association between shooting efficiency and winning in both the Women's U19 World Cup and the Women's European Championship; however, the magnitude of the coefficients cannot be directly compared across studies due to differences in gender, age, competition formats, and outcome variables. For the CBA, this result supports the use of relative shooting efficiency as a key metric in game analysis. The relationship between turnover rate and offensive rebound rate and net scoring reflects two distinct aspects of possession utilization: the former primarily indicates whether an offense can convert a possession into points before

losing the ball, while the latter primarily reflects the ability to regain possession after a missed shot and continue the offensive sequence. In the baseline model, a 1 percentage point increase in the difference in turnover rate corresponds to an average decrease of approximately 1.322 points in net scoring margin; a 1 percentage point increase in the difference in offensive rebound rate corresponds to an average increase of approximately 0.450 points in net scoring margin. However, the overall turnover rate for a game cannot distinguish between live-ball turnovers and dead-ball turnovers, nor does the offensive rebound rate directly reflect scoring efficiency following a rebound. Therefore, this study focuses solely on the loss of possession and the ability to sustain the offense. Furthermore, the four-factor differential between the home and away teams reflects both the home team's performance and the opponent's performance; an improvement in relative effective field goal percentage may stem either from an improvement in the home team's offense or from limiting the opponent's shooting efficiency. Consequently, each performance metric should be interpreted within the context of clearly defined comparators and standardized methods (Hughes and Bartlett, 2002).

5.2 The Direction of the Relationship Between Free-Throw Rate and Net Points Scored

The difference in free-throw rate is a finding in this study that warrants further discussion. Its correlation coefficient with net points scored was −0.062 before adjustment; however, after controlling for other game performance metrics and pre-game matchup conditions, the partial correlation coefficient shifted to 0.557. The regression coefficient in the baseline fixed-effects model was also positive. This suggests that the marginal and conditional relationships between free-throw rate and net points scored are not the same. The correlations also show that the difference in free throw rate is negatively correlated with the difference in effective field goal percentage and positively correlated with the difference in turnover rate. The combined variation of these factors means that the relationship observed when examining free throw rate in isolation may differ in direction from the relationship observed under conditions where other performance metrics are similar. Therefore, one cannot conclude, based on the unadjusted negative correlation, that the contribution of free throw points is detrimental to the game's outcome.

This study employs the free throw ratio (FTR = FTM/FGA), a calculation consistent with the definitions used by Kubatko et al. (2007) and Tománek et al. (2026)This metric is primarily influenced by free throw opportunities, free throw shooting ability, and the number of field goal attempts; therefore, it cannot be equated with free throw percentage, nor does it alone represent the ability to draw fouls. Due to the lack of information on the timing of free throws, types of fouls, and the score at the time, this study cannot determine whether the reversal in direction was caused by mechanisms such as tactical fouls in the fourth quarter or catch-up strategies.

5.3 Consistency in the Relationship Between Pre-Match Relative Strength and the Four Factors

Previous research has shown that basketball statistics must be interpreted in the context of opponent strength, the schedule, and the stage of the game. For example, Sansone et al. (2024)found in high-level European men's basketball that the schedule, travel, and situational factors were all associated with key game statistics; Gómez et al. (2013)analyzed the relationship between game context and offensive performance from the perspectives of possession and different game phases. This study primarily examines whether different pre-game strength relationships influence the relationship between the same home-away team technical efficiency differences and the final point differential.

Grouped regression analysis showed that the direction of the positive or negative association between the four factors and the home team's goal differential was consistent across the three types of pre-match head-to-head scenarios. To test whether the coefficients differed across these scenarios, this study

calculated the differences in coefficients among the three scenarios along with their 95% confidence intervals and conducted a joint Wald test. The results show that the 95% confidence intervals for all 12 coefficient differences included 0, and the joint tests for each of the four factors individually did not reach the level of significance; the overall joint test for the four factors was also not significant ($p = 0.805$). This indicates that, under the sample and model used in this study, no significant differences were found in the association between the four factors and the home team's point differential based on different pre-match strength-of-opponent scenarios. This provides direct statistical evidence for determining whether differences exist between these scenarios.

5.4 Contextual Differences in Assist Performance and Game Pace

Compared with the four factors, the assist-to-field-goal ratio and game tempo exhibit some situational differences. The interaction model shows that the coefficient for the assist-to-field-goal ratio in away-team-dominant situations is lower than in evenly matched situations, while the coefficient for game pace in home-team-dominant situations is higher than in evenly matched situations. However, particular caution is needed when interpreting the assist-to-field-goal ratio. This metric reflects the proportion of made field goals recorded as assists; therefore, it does not fully capture passing quality, tactical execution, or teamwork.

Similarly, the association between a faster pace and larger point differentials in home-team-dominant scenarios does not imply that actively accelerating the pace will necessarily widen the lead. The R^2 of the interaction model increased only slightly from 0.952 to 0.953 relative to the baseline model, and there is a lack of evidence from tests corrected for multiple comparisons. Therefore, these two findings should be treated as exploratory clues and should not be used to draw tactical conclusions that strong teams should always speed up or weak teams should always slow down.

6 Conclusion

6.1 Limitations of the Study

(1) Both the explanatory variables and the point differential are derived from the same game; the results should be interpreted as post-game correlation analysis. The model's high within-sample R^2 partially reflects this correlation and should not be regarded as the independent causal contributions of the four factors or as a measure of pre-game predictive accuracy. Team fixed effects also do not fully account for time-varying factors such as injuries, lineup rotations, and in-season tactical adjustments.

(2) Aggregate full-game data cannot distinguish between different game segments, real-time score situations, and types of offense, nor can it reconstruct the chronological sequence of technical performance and score changes. Existing research based on possession sequences suggests that different time periods and contexts require separate analysis(Gómez et al., 2013). Future research could combine per-possession data with video footage to examine types of turnovers, second-chance finishes, sources of free throws, and tactical adjustments before and after score changes, thereby further elucidating the formation process of game-wide correlations.

(3) The conclusions apply to the selected CBA regular-season games and cover only those matches in which both teams had completed at least five games prior to the match. They cannot yet be directly generalized to the playoffs, the early part of the season, other leagues, or women's and youth competitions. The strength classification method loses information regarding consecutive win rates; in the future, dynamic strength metrics—such as consecutive pre-match strength differentials and factors accounting for schedule difficulty—could be used to test for nonlinear relationships and conduct equivalence tests based on predefined thresholds of practical significance.

6.2 Practical Recommendations

(1) Establish post-game comparison records centered on four key factors. This study observed a consistent relationship between these four factors and point differential across three types of pre-game matchups involving teams of varying strengths. Based on this, it is recommended that teams retain field goal percentage, turnover rate, offensive rebound rate, and free throw rate as common post-game evaluation metrics across different matchups. After each game, record the metric values for both the home team and the opponent, as well as the difference between them, to distinguish whether the relative gap stems from a decline in the home team's performance or an improvement in the opponent's performance. By analyzing records from multiple consecutive games, identify recurring weaknesses to serve as the basis for further video analysis and the determination of training priorities.

(2) Use video review to translate metric gaps into specific training content. When a gap in effective field goal percentage persists, examine the shooting zones, the degree of defense pressure, and the shooting opportunities created through offensive plays; when the turnover rate is high, distinguish between types of turnovers—such as passing and dribbling errors—and the offensive phase in which they occur; when the offensive rebounding rate is low, examine rebounding opportunities, the players involved in the scramble, and their positioning. Based on the findings, select appropriate training content, such as shooting under defensive pressure, passing and receiving under physical contact, and drills linking rebounding to second-chance opportunities. Training priorities should be determined by the specific issues that repeatedly arise within the team; training time should not be allocated solely based on the magnitude of regression coefficients.

(3) Evaluate free throw metrics in conjunction with other offensive performance indicators. In this study, the simple correlation between the difference in free throw rate and net points scored was negative; however, after controlling for other game performance factors, it became a positive correlation, suggesting that teams should not rely solely on free throw rate to assess overall offensive performance. Since free-throw rate in this paper is defined as the ratio of free throws made to field goal attempts, it is recommended that these two metrics be recorded separately during game reviews. This will help distinguish whether changes are due to variations in the frequency of free-throw attempts relative to field goal attempts or changes in free-throw percentage. Additionally, a comprehensive evaluation should incorporate effective field goal percentage and turnover rate to avoid concluding that overall offensive quality has improved solely based on an increase in free-throw rate.

(4) Use contextual differences in pace and assist performance for ongoing observation. This study found that the game pace coefficient is higher in scenarios where the home team holds a pre-game advantage than in scenarios where both teams are evenly matched, while the coefficient of the difference in the assist-to-field-goal-made ratio is lower in scenarios where the away team holds an advantage than in scenarios where both teams are evenly matched. Teams can therefore use these two metrics as areas for further observation: in games where the home team holds an advantage, record whether changes in pace are accompanied by changes in shooting efficiency, turnover rate, and score; regarding assist performance, review game footage to examine the shooting opportunities created after passes, rather than relying solely on the assist-to-field-goal-made ratio to evaluate the quality of offensive organization. These situational differences should serve as exploratory clues; specific tactical adjustments should be tailored to the team's roster and evaluated through observations of consecutive games or practice matches.

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Authors' contributions

Yifan Zhang, Jiaqi Hao designed the study. Yifan Zhang ,Jiaqi Hao conducted the questionnaire distribution and data collection. Yifan Zhang performed the statistical analyses.Qian Huang supervised the study. All authors participated in writing and reviewing the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding

The authors declare that no financial support was received for the research and/or publication of this article.

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Ethics approval and consent to participate

This study involved a secondary analysis of publicly available, aggregated team-level statistics from Chinese Basketball Association (CBA) regular-season games. No participants were recruited, no interventions were conducted, and no identifiable personal or health data were collected or analysed. Ethics committee review was not sought for this study.

Consent to Participate declaration

Consent to participate: Not applicable.

Consent for publication

Not applicable. The manuscript does not contain identifiable individual information, photographs, or videos.

Availability of data and materials

The source game statistics were obtained from the CBA official website and Sina Sports, as described in the Methods section. The compiled game-level dataset used in the analyses, together with variable definitions, is provided in Additional file 1.

Competing interests

The authors declare that they have no competing interests.