



Choice of Experimental Design

This project investigates factors influencing the scoring performance of basketball players. To achieve the study's objectives, a 3<sup>2</sup> factorial design was chosen for the experiment. Specifically, a 3<sup>2</sup> factorial design was implemented, which is a subset of the 3<sup>k</sup> class of factorial designs. These designs are commonly utilized as foundational frameworks for exploring multiple factors, with each factor having three levels. In this study, the scope is limited to two factors.

Performing the Experiment

The experiment will be conducted as a 3x3 factorial design with two blocking levels (morning and evening). Three players will be recruited to participate in the study. During each treatment run, each player will attempt 10 shots, and the number of successful shots will be recorded. This process will be repeated four times to ensure replication and assess the stability of the response. Each repetition will be performed at a different spot within each distance level.

The two factors under investigation are as follows:

1. Distance to the basket: Measured at three levels — 4.57 meters, 6.71 meters, and 12.8 meters.
2. Basketball player height: Categorized into three levels — above standard height, standard height, and below standard height.

The model design for the experiment is

$$y_{ijk} = \mu + \delta_i + \gamma_j + (\delta\gamma)_{ij} + \beta_k + e_{ijk} \begin{cases} i = 1, 2, 3. (Distance) \\ j = 1, 2, 3. (Height) \\ k = 1, 2 (Block) \\ e_{ijk} \sim N(0, \sigma^2) \end{cases}$$

Location of Experiment

The project was carried out at Bartlett Stadium in College Park, Atlanta, Georgia.

Statistical Analysis of the Data

Descriptive Analysis

The analysis revealed that players performed best when shooting from a distance of 6.71 meters (D2) with a mean score of 7.37 (SD = 1.64), followed closely by 4.57 meters (D1) with a mean score of 7.33 (SD = 1.58). However, performance significantly declined at 12.8 meters (D3), which had the lowest

mean score of 6.04 (SD = 2.07), indicating that longer distances posed greater challenges (See Table 1). Players above the standard height (6 ft 6 in) demonstrated the highest mean score of 7.67 (SD = 2.04), suggesting a positive correlation between height and scoring accuracy, while shorter players had the lowest mean score of 6.50 (SD = 1.56) (See Table 2). Additionally, players performed better during morning sessions (M = 7.33, SD = 1.74) compared to evening sessions (M = 6.50, SD = 1.90), likely due to reduced fatigue or improved energy levels earlier in the day (See Table 3). These findings suggest that shooting performance is optimized under conditions involving medium distances (6.71 meters), taller players, and morning sessions.

Table 1: Summary Statistics by Distance

Analysis Variable : Result1							
Distance	N Obs	N	Mean	Std Dev	Median	Minimum	Maximum
D1	24	24	7.3333333	1.5788457	7.5000000	5.0000000	10.0000000
D2	24	24	7.3750000	1.6368714	7.0000000	4.0000000	10.0000000
D3	24	24	6.0416667	2.0742556	6.0000000	3.0000000	10.0000000

Table 2: Summary Statistics by Height

Analysis Variable : Result1							
Height	N Obs	N	Mean	Std Dev	Median	Minimum	Maximum
Above	24	24	7.6666667	2.0359095	8.5000000	3.0000000	10.0000000
Below	24	24	6.5000000	1.5603790	6.5000000	4.0000000	9.0000000
Standard	24	24	6.5833333	1.7916877	7.0000000	3.0000000	9.0000000

Table 3: Summary Statistics by Session

Analysis Variable : Result1							
Session	N Obs	N	Mean	Std Dev	Median	Minimum	Maximum
Evening	36	36	6.5000000	1.9048809	6.5000000	3.0000000	10.0000000
Morning	36	36	7.3333333	1.7402791	7.0000000	4.0000000	10.0000000

The Boxplots

The boxplot analysis highlights that player performance is influenced by distance, height, and session timing. Players performed best at a distance of 6.71 meters (D2), with higher median scores and moderate variability, while performance declined significantly at 12.8 meters (D3), showing the lowest median and highest variability (See Figure 1). Taller players (above standard height) had the highest median scores, demonstrating the advantage of height, whereas shorter players (below standard height) had the lowest scores (See Figure 2). Additionally, players performed better in the morning, with higher median scores and less

variability, compared to the evening when performance and consistency declined (See Figure 3). These findings underscore the impact of optimal distance, player height, and session timing on basketball shooting accuracy.

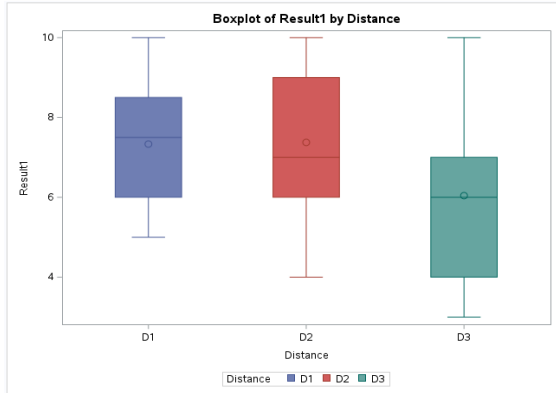


Figure 1: Boxplot of Result1 by Distance

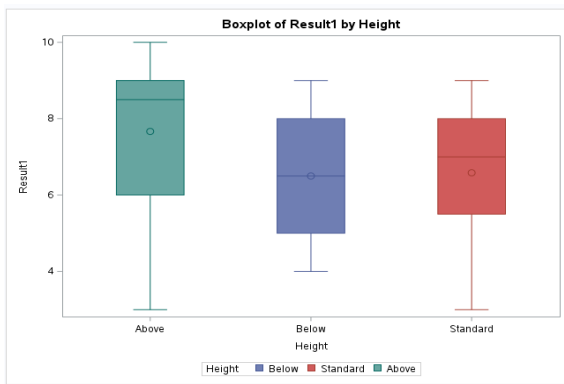


Figure 2: Boxplot of Result1 by Height

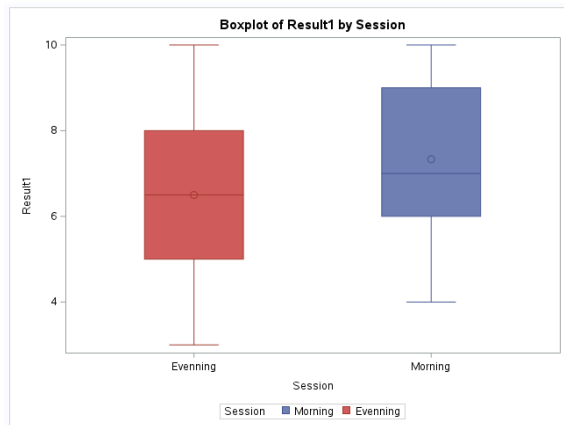


Figure 3: Boxplot of Result1 by Session

*Mean Effect Plots*

The line plots reveal key insights into the factors influencing basketball performance. Performance by distance shows that players achieve the highest scores at D2 (6.71 meters), with an average score near 8, followed closely by D1 (4.57 meters), while performance drops significantly at D3 (12.8 meters), where the mean score is around 6, likely due to increased difficulty at greater distances (See Figure 4). For height, players above the standard height perform the best, with a mean score close to 9, while players below the standard height have the lowest mean score around 6, indicating a height advantage in scoring accuracy. Players of standard height perform moderately, with an average score of approximately 7 (See Figure 5). Regarding session timing, players perform better in the morning session, with an average score of 7, compared to the evening session, where the mean score decreases to around 6, likely due to lower energy levels or increased fatigue (See Figure 6). These findings underscore the importance of moderate distances, taller players, and scheduling games in the morning to optimize performance.

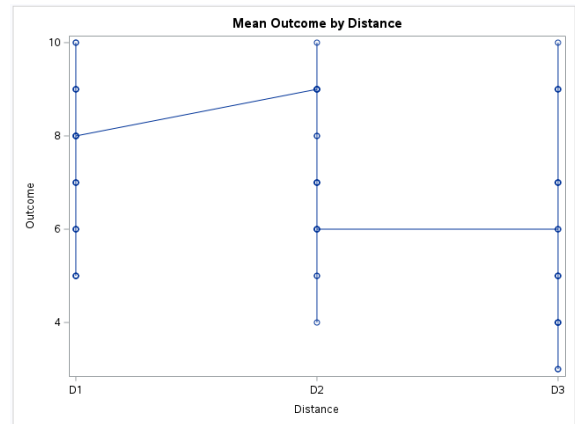


Figure 4: Line plot of Mean Outcome by Distance

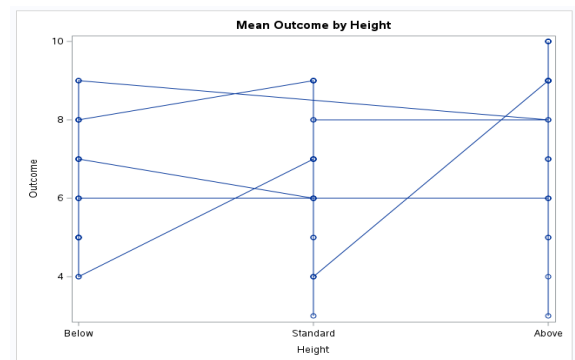


Figure 5: Line plot of Mean Outcome by Height

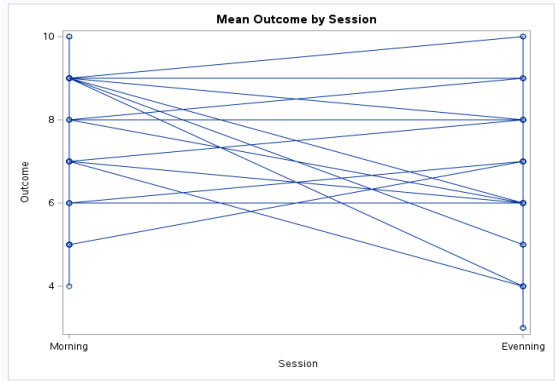


Figure 6: Line plot of Mean Outcome by Session

**Assumptions Check**

The Shapiro-Wilk test indicates that the residuals follow a normal distribution ( $W = 0.9878$ ,  $p = 0.7152$ ), as the p-value is greater than the significance level of 0.05 (See Table 4). The Q-Q plot further supports this, with the residuals aligning closely along the diagonal reference line, suggesting minimal deviations from normality (See Figure 8). The histogram of residuals shows a symmetric distribution that aligns well with the overlaid normal curve, indicating no significant outliers (See Figure 7). Additionally, a visual inspection of the residuals versus fitted values plot confirms that the residuals exhibit constant variance (homoscedasticity), as there is no clear pattern or funnel shape in the spread (See Figure 9). Together, these results confirm that the residuals satisfy the assumptions of normality and constant variance, supporting the validity of the ANOVA model.

Table 4: Normality Assumption Test for Residual

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.98777	Pr < W	0.7152
Kolmogorov-Smirnov	D	0.116539	Pr > D	0.0167
Cramer-von Mises	W-Sq	0.101478	Pr > W-Sq	0.1070
Anderson-Darling	A-Sq	0.4888	Pr > A-Sq	0.2235

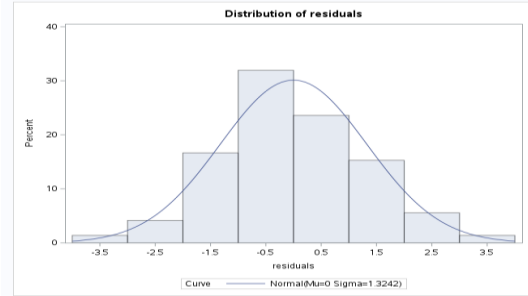


Figure 7: Histogram for Residual

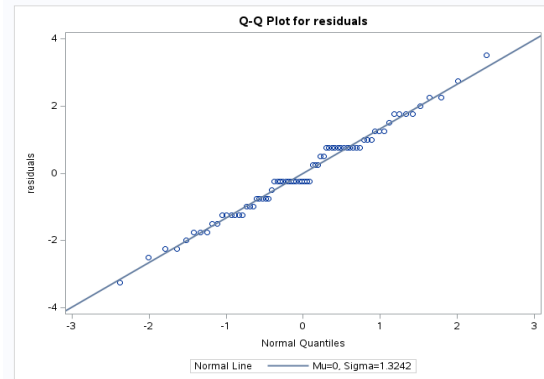


Figure 8: Q-Q plot for Residual

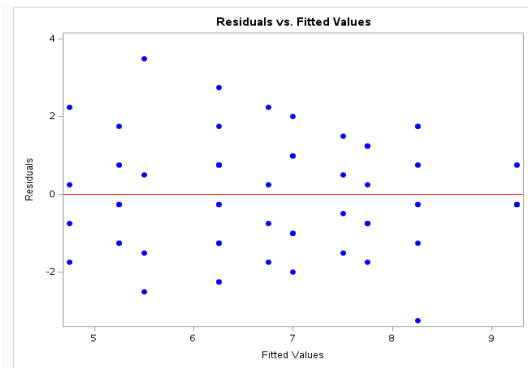


Figure 9: Residuals Vs. Fitted Values Plot

**Fitting the Model**

The ANOVA results revealed that the overall model was statistically significant ( $F(17, 54) = 3.09$ ,  $p = 0.0008$ ,  $R^2 = 0.49$ ), indicating that the factors and their interactions explained approximately 49% of the variance in performance. For the main effects, Distance had a significant impact on performance ( $F(2, 54) = 5.98$ ,  $p = 0.0045$ ), with performance varying across distances (D1, D2, D3). Height also had a significant effect ( $F(2, 54) = 4.41$ ,  $p = 0.0168$ ), suggesting that players' height categories (Above, Below, Standard) influenced performance.

Additionally, Session was significant ( $F(1, 54) = 5.42, p = 0.0237$ ), indicating differences in performance between morning and evening sessions. Interaction effects revealed that Distance  $\times$  Session was significant ( $F(2, 54) = 3.63, p = 0.0331$ ), as was Height  $\times$  Session ( $F(2, 54) = 6.58, p = 0.0028$ ), suggesting that combinations of these factors influenced performance. However, the interactions Distance  $\times$  Height ( $F(4, 54) = 0.50, p = 0.7380$ ) and Distance  $\times$  Height  $\times$  Session ( $F(4, 54) = 0.97, p = 0.4333$ ) were not significant. These results highlight the significant independent and combined effects of Distance, Height, and Session on performance, with certain factor combinations showing more influence than others.

Table 5: Analysis of Variance (ANOVA)

Dependent Variable: Result1					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	17	121.0000000	7.1176471	3.09	0.0008
Error	54	124.5000000	2.3055556		
Corrected Total	71	245.5000000			

R-Square	Coeff Var	Root MSE	Result1 Mean
0.492872	21.95285	1.518406	6.916667

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Distance	2	27.58333333	13.79166667	5.98	0.0045
Height	2	20.33333333	10.16666667	4.41	0.0168
Distance*Height	4	4.58333333	1.14583333	0.50	0.7380
Session	1	12.50000000	12.50000000	5.42	0.0237
Distance*Session	2	16.75000000	8.37500000	3.63	0.0331
Height*Session	2	30.33333333	15.16666667	6.58	0.0028
Distance*Height*Session	4	8.91666667	2.22916667	0.97	0.4333

*Post-Hoc Analysis*

The pairwise comparisons revealed significant differences in performance for Distance but not for Height. For Distance, the least squares mean (LSMeans) were D1 = 7.33, D2 = 7.38, and D3 = 6.04. Pairwise comparisons showed that performance at D3 was significantly lower compared to D1 ( $p = 0.0372$ ) and D2 ( $p = 0.0303$ ), while there was no significant difference between D1 and D2 ( $p = 0.9964$ ) (See Table 6). For Height, the LSMMeans were Above = 7.67, Below = 6.50, and Standard = 6.58, but none of the pairwise differences were statistically significant: Above vs. Below ( $p = 0.0720$ ), Above vs. Standard ( $p = 0.1020$ ), and Below vs. Standard ( $p = 0.9860$ ) (See Table 7). The visualization for Distance showed significant differences between D1 vs. D3 and D2 vs. D3 (blue lines) (See Figure 10), while all comparisons for Height were not significant (red lines) (See Figure 11). These results indicate that performance is significantly influenced by Distance,

with better performance at shorter distances, whereas Height does not have a statistically significant impact on performance.

Table 6: Post-Hoc Comparison for Distance

**The GLM Procedure**  
**Least Squares Means**  
**Adjustment for Multiple Comparisons: Tukey**

Distance	Result1 LSMEAN	LSMEAN Number
D1	7.33333333	1
D2	7.37500000	2
D3	6.04166667	3

**Least Squares Means for effect Distance**  
**Pr > |t| for H0: LSMean(i)=LSMean(j)**

**Dependent Variable: Result1**

i/j	1	2	3
1		0.9964	0.0372
2	0.9964		0.0303
3	0.0372	0.0303	

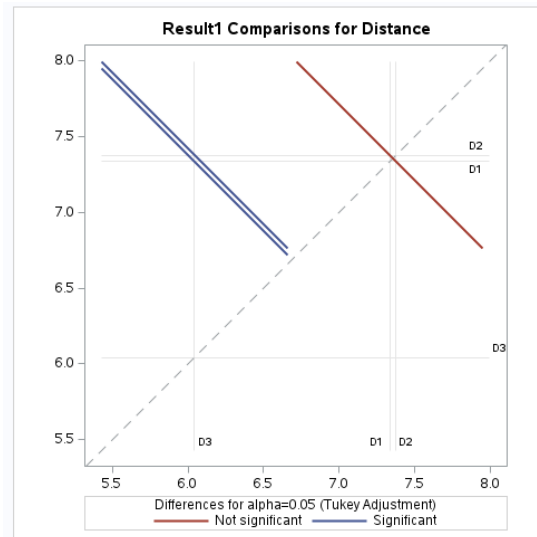


Figure 10: Post-Hoc Comparison for Distance

Table 7: Post-Hoc Comparison for Height

The GLM Procedure  
Least Squares Means  
Adjustment for Multiple Comparisons: Tukey

Height	Result1 LSMEAN	LSMEAN Number
Above	7.86688867	1
Below	6.50000000	2
Standard	6.58333333	3

Least Squares Means for effect Height Pr >  t  for H0: LSMean(i)=LSMean(j)			
Dependent Variable: Result1			
i\j	1	2	3
1		0.0720	0.1020
2	0.0720		0.9860
3	0.1020	0.9860	

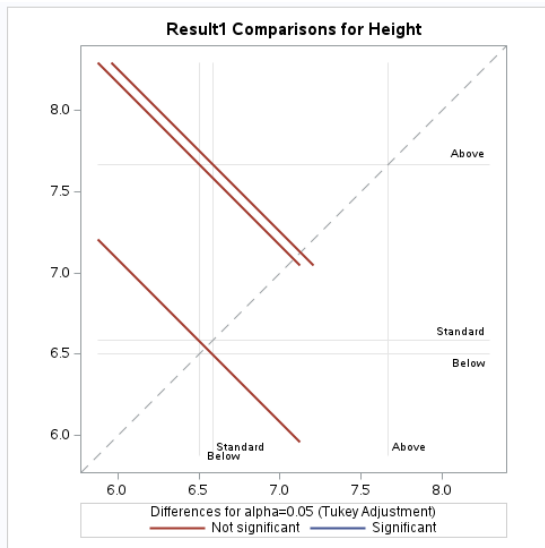


Figure 11: Post-Hoc Comparison for Height

Interaction Plots

The interaction plots reveal significant combined effects of session timing with distance and height on performance. For the Distance × Session interaction, performance at D1 (4.57 meters) remains stable across sessions, while performance at D2 (6.71 meters) and D3 (12.8 meters) improves notably in the morning, indicating that session timing has a greater impact on longer distances (See Figure 12). For the Height × Session interaction, players above the standard height show significantly better performance in the morning compared to the evening, while players below the standard height perform

slightly better in the evening. Players of standard height exhibit consistent performance across sessions with minor improvement in the morning (See Figure 13). These findings suggest that morning sessions enhance performance at challenging distances and for taller players, while evening sessions may benefit shorter players, underscoring the interplay between physical attributes, task difficulty, and session timing.

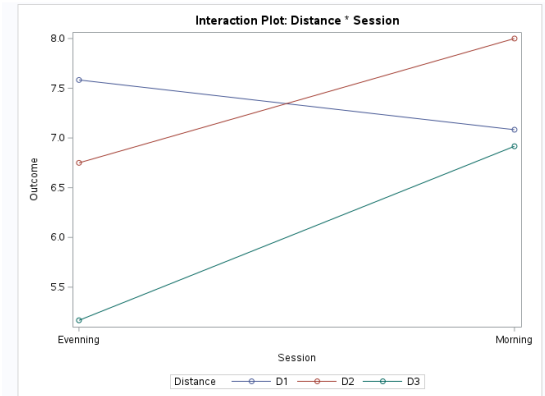


Figure 12: Interaction Plot of Distance by Session

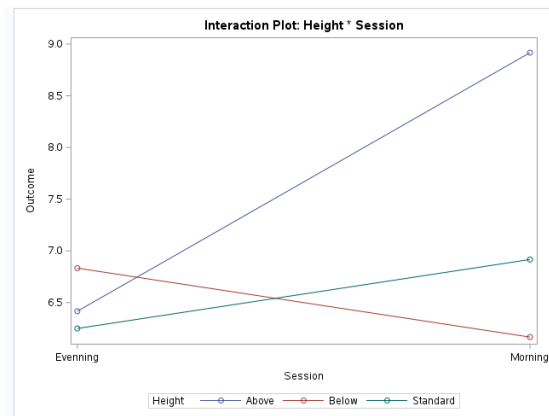


Figure 13: Interaction Plot of Height by Session

CONCLUSION

The results of this study highlight the significant effects of distance, height, and session timing on basketball shooting performance. Players performed best at a medium distance (6.71 meters), with performance declining significantly at the longest distance (12.8 meters). Taller players (above the standard height) achieved the highest scores, while shorter players had lower performance. Morning sessions yielded better results compared to evening

sessions, particularly for longer distances and taller players, suggesting an interplay between session timing, physical attributes, and task difficulty. The findings emphasize the importance of optimizing game strategies by considering these factors to enhance player performance.

#### RECOMMENDATION

Based on the results, coaches and trainers should focus on medium shooting distances (e.g., 6.71 meters) during training and game strategy to maximize performance. Taller players should be positioned for crucial shots during morning sessions, where their performance is significantly better, while shorter players might benefit from evening games. Additionally, training programs should account for player height and session timing to improve shooting accuracy at challenging distances. Future studies should explore other factors, such as mental fatigue and environmental conditions, to further enhance player performance insights.