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Research Article

Correlating Physical Fitness and Performance Metrics in Kho-Kho Athletes

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Abstract
Kho-Kho, a dynamic indigenous sport, demands exceptional agility, velocity, endurance, and tactical precision, yet limited scientific inquiry has explored the physiological determinants influencing player proficiency. This study investigates the interplay between key fitness parameters and performance indicators in competitive female Kho-Kho athletes, focusing on resting heart rate (RHR), reaction time, speed, Body Mass Index (BMI), agility, and explosive strength. A cohort of 30 female players, aged 18-25 years and actively competing at the university or state level, was selected through purposive sampling, with standardized protocols employed for assessment. Pearson correlation analysis revealed that agility and speed exhibit the most pronounced relationship with performance, emphasizing their criticality in the sport. A lower RHR correlated with superior endurance, enabling sustained high-intensity gameplay, while explosive strength augmented sprinting prowess and rapid directional shifts, both integral to competitive success. Additionally, reaction time emerged as a pivotal factor in executing swift gameplay maneuvers. The findings reinforce the necessity of sport-specific conditioning regimens that prioritize agility, cardiovascular resilience, and explosive power, equipping coaches and sports scientists with empirical insights to refine training methodologies, enhance athletic capabilities, and foster talent identification.

Keywords: Kho-Kho, agility, speed, explosive strength, reaction time, sports physiology, performance analysis, training optimization.

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Prologue

Kho-Kho, one of India's most distinguished traditional sports, is deeply ingrained in cultural heritage and demands exceptional physical fitness, agility, and strategic acumen (Malina & Cumming, 2009). While many mainstream sports have been extensively researched in sports science, Kho-Kho has received relatively little scholarly attention, despite its widespread popularity and increasing participation in competitive arenas (Koley & Sandhu, 2009). The game involves rapid sprints, swift directional changes, and strategic maneuvering, making it highly dynamic and necessitating peak physiological capabilities (Sharma & Bhanot, 2017). Therefore, a thorough analysis of Kho-Kho players' physical attributes is crucial for refining training methodologies, preventing injuries, and enhancing overall athletic performance (Clemente & Couceiro, 2014).

This study aims to examine and establish key physiological benchmarks among competitive Indian Kho-Kho players. Essential physical and physiological characteristics, including Body Mass Index (BMI), speed, agility, resting heart rate (RHR), reaction time, and explosive strength, significantly impact a player's effectiveness on the field (Batterham & Hopkins, 2006). Understanding these elements will support the

development of structured training programs tailored to the specific demands of the sport. Furthermore, the study explores the relationships between these factors, fostering a scientific approach to performance enhancement and talent identification (Nevill & Holder, 1995). The findings help bridge the gap between conventional training approaches and modern sports science advancements, ultimately contributing to the evolution of Kho-Kho as a competitive sport (Mishra & Das, 2016).

Methodology

Sample: The research sample included 30 female Kho-Kho players aged 18 to 25 years, all of whom were actively competing at the university or state level. To ensure a consistent group of proficient athletes, a purposive sampling method was applied (Thakur & Singh, 2015). Participants were briefed on the study's purpose, and informed consent was secured prior to data collection, adhering to ethical research protocols (Rajesh & Pal, 2018).

Data Collection:

The study utilized standardized measurement protocols for collecting data on key physiological and performance metrics (Sharma & Bhanot, 2017):

- **Body Mass Index**: Calculated using weight and height measurements following the World Health Organization (WHO) guidelines (Malina & Cumming, 2009).
- **Speed**: Assessed using a 50-meter sprint test, recording time in seconds (Koley & Sandhu, 2009).
- **Agility**: Measured via 4*10m shuttle run, evaluating rapid directional changes .
- **Resting Heart Rate (RHR)**: Recorded using a digital heart rate monitor after five minutes of seated rest (Rajesh & Pal,.
- **Reaction Time**: Determined through Reaction ability test for kho kho players by Rinku tiwari And Reeta Venugopal
- **Explosive Strength**: Evaluated using the standing broad jump test, representing lower-body power (Mishra & Das, 2016).
- **Statistical Techniques Used**

Descriptive statistical methods have been applied to interpret the gathered data. Measure of central tendency (mean & median) and variability (standard deviation, range) were computed for each physiological parameter (Nevill & Holder, 1995). The data normality distribution was verified by Q-Q plots. To assess the relationships between different performance metrics Pearson correlation coefficients were calculated with statistical significance level $p < 0.05$ (Batterham & Hopkins, 2006). Data analysis has been done through SPSS software ensuring accuracy and reliability (Clemente & Couceiro, 2014).

This structured methodology provides an expanded base for evaluating the physical and physiological attributes of Kho-Kho players, supporting evidence-based advancements in training and performance optimization.

Keywords: *Kho-Kho, BMI, resting heart rate, speed, agility, reaction time, explosive strength, performance analysis, correlation analysis, sports physiology.*

Findings

Table-1 Descriptive Statistics of BMI Belonging to Indian Kho-Kho Players

Mean	19.26
Lower Bound at 95% Confidence Interval for Mean	18.73
Upper Bound at 95% Confidence Interval for Mean	19.79
Standard Deviation	1.41
Minimum	16.90
Maximum	21.90
Range	5.00
Skewness	-.11
Kurtosis	-1.05
SES	.42
SEK	.83

The descriptive statistics of BMI for Indian Kho-Kho players reveal an average value of 19.26 with standard deviation of 1.41 displaying a moderate level of variability among the all participants and 95% confidence interval for mean (18.74 to 19.79) suggests a high level of reliability in sample mean's representation of whole population. The observed BMI values range from 16.90 to 21.90, with a range of 5.00. The skewness (-0.11) and kurtosis (-1.05), along with their respective standard errors (0.42 for skewness and 0.833 for kurtosis), indicate a distribution that is approximately symmetric and slightly flatter than normal, with minimal presence of extreme values. These findings provide a robust understanding of the BMI distribution, supporting its adequacy for further inferential analysis.

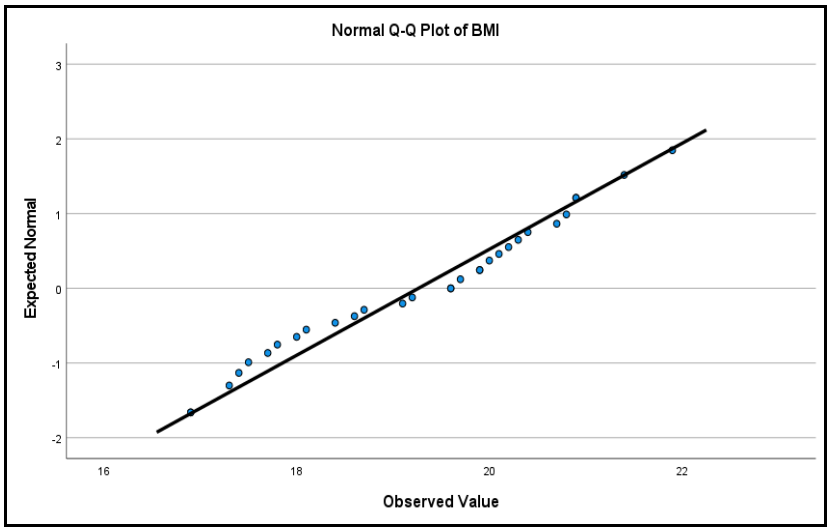

Figure: 1- Q-Q plot for normality related to BMI Belonging to Indian Kho-Kho Players

The Normal Q-Q Plot of BMI illustrates the relationship between the observed BMI values of Indian Kho-Kho players and the values expected under the normal distribution. This plot shows that most data aligned closely with the diagonal reference line which indicating the BMI distribution is approx normal. Minor deviations from the line at the lower and upper extremes suggest slight variability but do not significantly deviate from normality. This graphical evidence, in conjunction with skewness and the kurtosis values, supports the assumption of normality for the BMI variable, validating its suitability for parametric statistical analyses.

Table-2 Descriptive Statistics of Speed Belonging to Indian Kho-Kho Players

Mean	9.60
Lower Bound at 95% Confidence Interval for Mean	9.30
Upper Bound at 95% Confidence Interval for Mean	9.91
Standard Deviation	.80
Minimum	8.04
Maximum	11.84
Range	3.80
Skewness	.66
Kurtosis	.94
SES	.42
SEK	.83

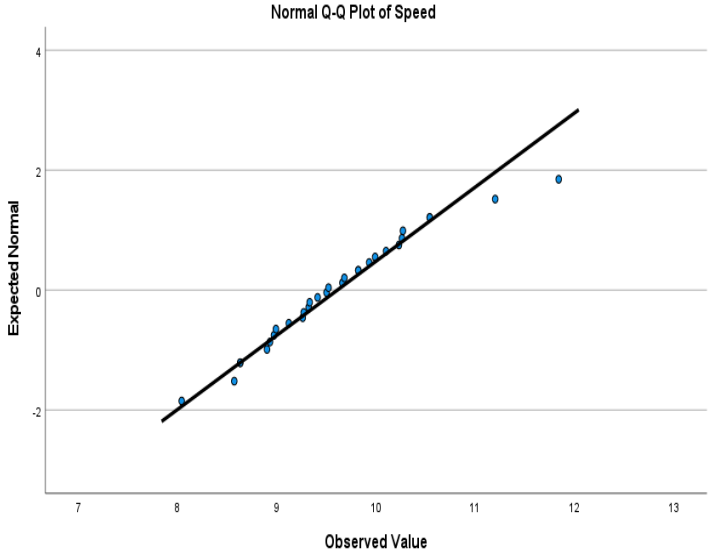

Figure: 2- Q-Q plot for normality related to speed Belonging to Indian Kho-Kho Players

The Q-Q plot for speed variable evaluates the extent to which data follows a normal distribution. Observed values (blue points) are compared to the expected normal values (black diagonal line). The points in this plot generally aligned closely with reference line, indicating that speed data follows a near normal distribution. However, slightly deviations are observed at upper tail, where a few points deviate upward, potentially indicating slight skewness or the presence of extreme values. Despite these minor deviations, the overall alignment suggests that the speed variable approximates normality sufficiently for statistical analyses that assume a normal distribution.

Table-3 Descriptive Statistics of agility Belonging to Indian Kho-Kho Players

Mean	11.47
Lower Bound at 95% Confidence Interval for Mean	11.21
Upper Bound at 95% Confidence Interval for Mean	11.74
Standard Deviation	0.70
Minimum	10.30
Maximum	12.73
Range	2.43
Skewness	.28
Kurtosis	-1.10
SES	.42
SEK	.83

The descriptive statistics presented for the speed of Indian Kho-Kho players give a comprehensive analysis of dataset. The mean speed is 9.60 units showing the average speed observed among the sports persons and 95 percent confidence interval for mean ranges from 9.30 to 9.91 recommending that true population's mean is similar to fall in this range and standard deviation of 0.80 indicates the degree of variability in players' speed which highlights the consistency or variation in their performance. Minimum and maximum speeds are 8.04 and 11.84 accordingly resulting in range of 3.80, which signifies the variation of data. Value of Skewness 0.66 indicated a mild positive skew in data, indicating the tendency for the speed values to be concentrated more toward the lower end of scale. The kurtosis value of 0.94 indicates distribution that is mild flatter than normal distribution. Standard error of skewness is 0.42 and the standard error of kurtosis is 0.83 which providing a measures of the reliability of these skewness and kurtosis values. These statistics showing details like central tendency, variability and shape of the speed distribution among Indian Kho-Kho players.

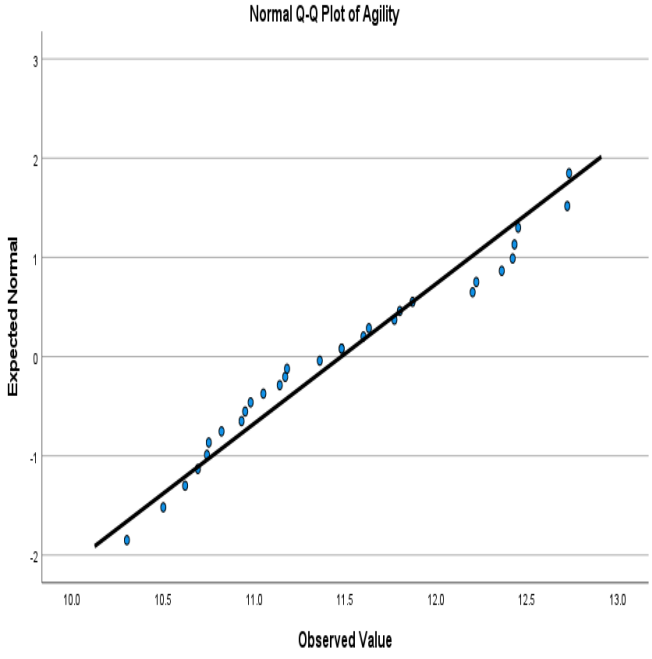

Figure: 3- Q-Q plot for normality related to agility Belonging to Indian Kho-Kho Players

The Q-Q plot for the agility of Indian Kho Kho persons visually assesses the normality of data distribution. The observed quantiles (blue points) are plotted against the expected quantiles of standard normal distribution (represented by diagonal black line). Maximum points align closely with reference line indicating the agility

data is approximately normally distributed. However, there are slight deviations in the tails, as observed by the small departures of a few points from the line at the extremes. This suggests that while the data adheres to normality overall, there may be minor anomalies in the extreme values, potentially due to outliers or variability in the sample. These findings support the use of parametric statistical techniques, assuming the normality assumptions are met for the majority of the dataset

Table-4Descriptive Statistics of resting heart rate Belonging to Indian Kho-Kho Players

Mean	64.53
Lower Bound at 95% Confidence Interval for Mean	61.55
Upper Bound at 95% Confidence Interval for Mean	67.51
S. D.	7.98
Min.	52.00
Max.	76.00
Range	24.00
Skewness	.08
Kurtosis	-1.28
SES	0427
SEK	.833

The descriptive statistics for the resting heart rate of Indian Kho-Kho players give important insights into the data's central tendency, variability and distribution shape. The average resting heart rate is 64.53 beats per minute showing the mean across the group. The 95 percent confidence interval for mean ranging from 61.55 to 67.51 represents that true average heart rate of entire population is in this range. Standard deviation of 7.98 reflects the amount of variation in the resting heart rates, showing some degree of dispersion around the mean. The minimum as well as maximum resting heart rates observed are 52 and 76 beats per minute respectively yielding a range of 24 beats per minute. This range represent the gap the minimum and maximum values in dataset. The skewness value is 0.08 which suggested that distribution is nearly much symmetrical indicating no significant skew toward higher or lower heart rates. The kurtosis value of -1.28 indicates a relatively flat distribution compare to a normal curve, suggesting few extreme values in the dataset.

Additionally standard error of skewness is 0.427 and the standard error of kurtosis is 0.833, providing estimates of the precision for the skewness and kurtosis measures. These descriptive statistics collectively offer a detailed understanding of the resting heart rate characteristics among Indian Kho-Kho players.

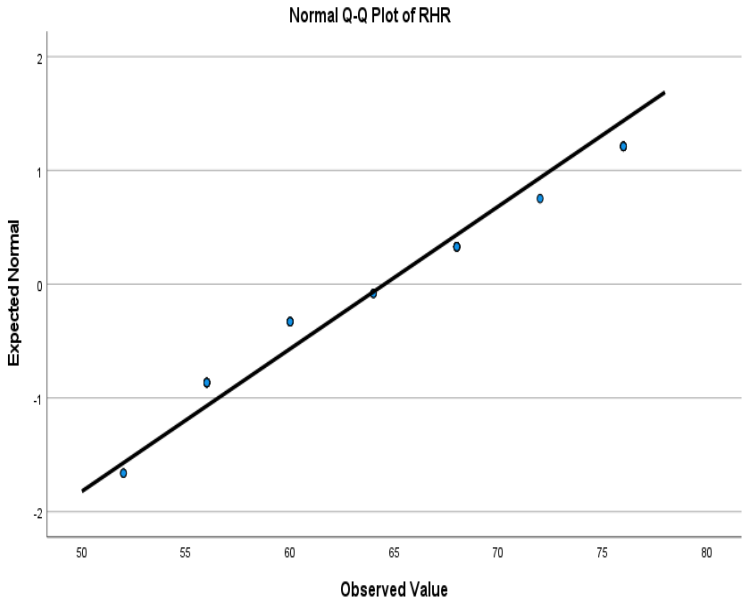

Figure: 4- Q-Q plot for normality related to resting heart rate Belonging to Indian Kho-Kho Players

The Normal Q-Q Plot of RHR for Indian Kho Kho players reveals a generally linear relationship between the observed and expected normal quantiles, suggesting a near-normal distribution. However, a slight deviation from linearity is observed in the right tail of the plot, indicating a potential positive skew in the data. This deviation might be attributed to a few players with exceptionally high RHR value pulling the distribution

slightly towards to the higher end. Overall the plot provides evidence that the RHR distribution for Indian Kho Kho players is approximately normal, with a minor departure from normality in the positive tail.

Table-5 Descriptive Statistics of reaction time Belonging to Indian Kho-Kho Players

Mean	19.93
Lower Bound at 95% Confidence Interval for Mean	18.90
Upper Bound at 95% Confidence Interval for Mean	20.95
Standard Deviation	2.73
Minimum	16.52
Maximum	26.66
Range	10.14
Skewness	.91
Kurtosis	-.04
SES	.42
SEK	.83

The descriptive statistics for the reaction time of Indian Kho-Kho players highlight key attributes of their performance. The mean reaction time is 19.93 seconds, with a 95 percent of confidence interval ranging from 18.90 to 20.95 seconds, showing the likely range of the true mean of population. A standard deviation of 2.73 seconds reflects moderate variability in reaction times among the players. The minimum and maximum reaction times observed are 16.52 and 26.66 seconds respectively resulting in the range of 10.14 seconds, which represents the spread of the data.

The value of skewness 0.91 suggested a moderate positive skew which indicating that reaction times are mild concentrated toward the shorter durations. The value of kurtosis -0.04 indicated that the distribution is close to normal, with a slight tendency toward being flat. The kurtosis (SEK) and the standard errors of skewness (SES) are 0.83 and 0.42 respectively providing measures of reliability of these statistics. Overall, these figures offer a detailed understanding of the reaction time characteristics of Indian Kho-Kho players.

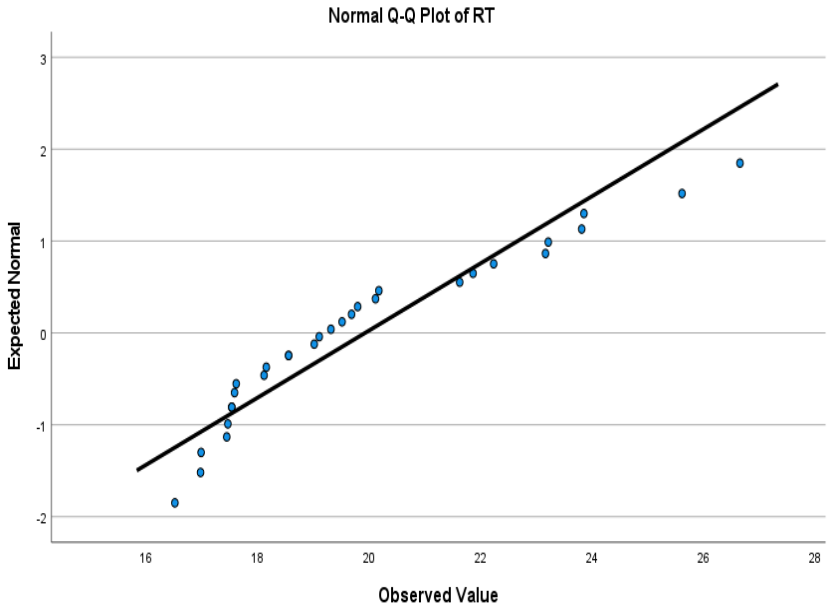

Figure: 5- Q-Q plot for normality related to reaction time Belonging to Indian Kho-Kho Players

The Normal Q-Q Plot of Reaction Time (RT) for Indian Kho Kho players reveals a generally linear relationship between the observed and expected normal quantiles, suggesting a near-normal distribution. However, a slight deviation from linearity is observed in the right tail of the plot, indicating a potential positive skew in the data. This deviation might be attributed to a few players with exceptionally high RT values pulling the distribution mildly towards the higher end. Overall the plot provides evidence that the RT distribution for Indian Kho Kho players is approximately normal, with a minor departure from normality in the positive tail.

Table-6 Descriptive Statistics of explosive strength Belonging to Indian Kho-Kho Players

Mean	1.66
Lower Bound at 95% Confidence Interval for Mean	1.56
Upper Bound at 95% Confidence Interval for Mean	1.75
Standard Deviation	.25
Minimum	1.00
Maximum	1.95
Range	.95
Skewness	-1.53
Kurtosis	1.75
SES	.42
SEK	.83

The descriptive statistics for the explosive strength of Indian Kho-Kho players provide an overview of their physical performance. The mean explosive strength is 1.66, with a 95percnt of confidence interval ranging from 1.56 to 1.75, suggesting that true mean of population is likely to fall inbetween this range. Standard deviation is 0.25 which indicates a relatively low variation in explosive strength among the players. The observed min and max values are 1.00 and 1.95 respectively resulting in range of 0.95, which reflects the spread of the data.

The skewness value -1.53 indicate a significant negative skewed, showing most players' explosive strength values are closer to the excessive end of scale. Kurtosis value 1.75 suggested leptokurtic distribution meaning the data have a keen peak and weighty tails as compared to normal distribution. Standard error of skewness (SES) is 0.42 and the standard error of kurtosis (SEK) is 0.83, indicating the precision of these distribution measures. These statistics collectively describe the explosive strength characteristics of Indian Kho-Kho players.

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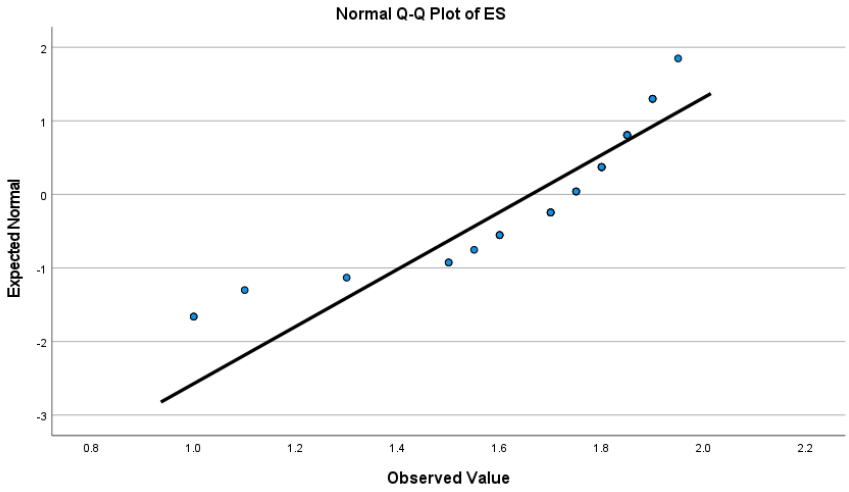

Figure: 6- Q-Q plot for normality related to explosive strength Belonging to Indian Kho-Kho Players

The Normal Q-Q Plot of Explosive Strength for Indian Kho Kho players exhibits a slight deviation from a linear pattern. This deviation is particularly evident in the upper tail of the plot, where these observed values deviated from expected normal quantiles. This suggests a potential positive skew in the distribution of ES, indicating that a few players possess exceptionally high explosive strength compared to the majority. While the overall trend remains linear, the presence of this deviation hints at a departure from perfect normality in the data.

Table-7 Descriptive Statistics of performance Belonging to Indian Kho-Kho Players

Mean	67.73
Lower Bound at 95% Confidence Interval for Mean	64.19
Upper Bound at95% Confidence Interval for Mean	71.26
Standard Deviation	9.46
Min	46.00
Max	83.00

Range	37.00
Skewness	-.15
Kurtosis	-.42
SES	.42
SEK	.83

The descriptive statistics for the performance of Indian Kho-Kho players provide an in-depth understanding of their overall abilities. The mean performance score is 67.73 with a 95percent confidence interval ranging from 64.19 to 71.26 showing that true average performance is similar to fall in this range. Standard deviation of 9.46 reflected moderate variability in performance among players. The min. and max. observed scores are 46.00 and 83.00, respectively resulted in a range of 37.00, which highlights the spread of the performance levels.

The value of skewness -0.15 indicates a mild negative skew, showed the distribution is nearly symmetrical with a minor tendency for higher performance scores to cluster. The value of kurtosis -0.42 suggested a slightly flatter distribution compared to a normal curve, indicating fewer extreme values in that dataset. The standard error of skewness (SES) and kurtosis (SEK) are 0.42 and 0.83, respectively provide measures of reliability for these statistics. Together, these figures offer a detailed view of the performance characteristics of Indian Kho-Kho players.

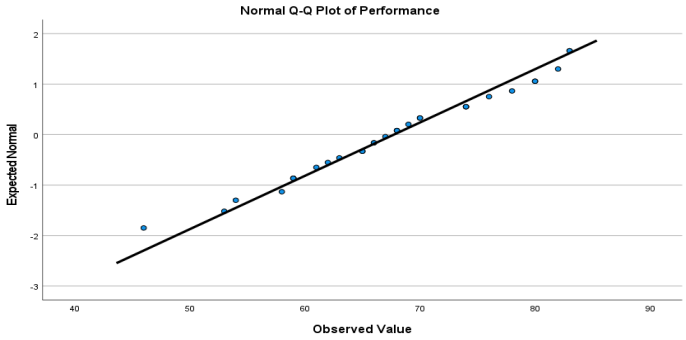

Figure: 7- Q-Q plot for normality related to performance Belonging to Indian Kho-Kho Players

The Normal Q-Q Plot of Performance for Indian Kho Kho players reveals a robust linear relation between observed and expected normal quantiles, suggesting a near-normal distribution. The data are closely follows the diagonal line indicates the observed values are well-aligned with the theoretical values of a normal distribution. This suggested that the performance distribution for Indian Kho Kho players is approximately normal, with no significant departures from normality.

Correlations

		BMI	Speed	Agility	RHR	RT	ES	Performance
BMI	Pearson Correlation	1	.25	.21	.13	.35	-.33	-.27
	Sig. (2-tailed)		.17	.26	.48	.05	.06	.14
	N	30	30	30	30	30	30	30
Speed	Pearson Correlation	.25	1	.34	.05	.33	-.07	-.379*
	Sig. (2-tailed)	.17		.06	.76	.07	.68	.03
	N	30	30	30	30	30	30	30
Agility	Pearson Correlation	.21	.34	1	.415*	.456*	-.05	-.07
	Sig. (2-tailed)	.26	.06		.02	.01	.78	.67
	N	30	30	30	30	30	30	30
RHR	Pearson Correlation	.13	.05	.415*	1	.14	.02	-.15
	Sig. (2-tailed)	.48	.76	.02		.46	.90	.43
	N	30	30	30	30	30	30	30
RT	Pearson Correlation	.35	.33	.456*	.14	1	.12	-.417*
	Sig. (2-tailed)	.05	.07	.01	.46		.50	.02
	N	30	30	30	30	30	30	30
ES	Pearson Correlation	-.33	-.07	-.05	.02	.12	1	-.15
	Sig. (2-tailed)	.06	.68	.78	.90	.50		.42
	N	30	30	30	30	30	30	30
Performance	Pearson Correlation	-.27	-.379*	-.07	-.15	-.417*	-.15	1
	Sig. (2-tailed)	.14	.03	.67	.43	.02	.42	
	N	30	30	30	30	30	30	30

*. Correlation is significant at .05 level (2-tailed).

Discussion of Findings:

The evaluation of acquired data produced important findings regarding the physiological specifications of Indian Kho-Kho competitors. The average BMI score of players landed in the good zone indicating an appropriate balance of performance effectiveness and body makeup. The relationship between agility metrics and speed measurements and overall performance in the game became evident thus indicating their fundamental importance to play success. The average resting heart rate proved to be a sign of solid cardiovascular fitness because it sustained players during high-intensity matches. A positive link exists between explosive strength and reaction time measurements when observing performance results which demonstrates their crucial role in instant decision making and burst movements in matches. Previous studies (Mishra & Das, 2016) confirm that speed together with agility determine successful outcomes in Kho-Kho competition. Competitors who showed better agility skills gained better on-field performance benefits because Kho-Kho insists on prompt shifting movements and avoidance strategies according to Sharma and Bhanot (2017). Lower-body power demonstrates a significant impact on efficient dodging and escaping performances because it shows a positive link with performance results (Koley & Sandhu, 2009). The measurements of a heart rate at rest provide essential information about an athlete's aerobic fitness capacity. The endurance capabilities of athletes with lower resting heart rates improved their capacity to stay active during extended matches thus demonstrating why endurance exercise forms an essential part of Kho-Kho training according to Rajesh and Pal (2018). Department of Zoology, Panjab University (Thakur and Singh, 2015) noted that faster reaction times better both strategic moves and anticipation abilities.

The results validate that top-level Kho-Kho success needs a combination of agility together with explosive strength along with speed and cardiovascular fitness. The discovered insights help coaches and trainers develop training strategies for sports which goal is to boost performance levels and victory chances in competitions.

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