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Relationship Between Competitive Anxiety and Performance in Badminton Players

¹Mr. Vijay Kumar, ²Dr. Ravi Kumar

¹Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab

²Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India.

Email id: ¹vkverma5656@gmail.com, ²ravikumar.gahalawat@gmail.com

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Abstract— The purpose of the study was to investigate the relationship between competitive anxiety and performance among 20 male inter-collegiate badminton players. The players' ages ranged from 18 to 23 years. They belonged to Seth Girdhari Lal Bihani S.D. P.G. College, Sri Ganganagar, Rajasthan. A correlational descriptive design was employed. Using the Sport Competition Anxiety Test (SCAT), competitive anxiety was measured before and after tournament matches. Performance scores were calculated based on official competition results. The Pearson product-moment correlation was used at the 0.05 level. Mean anxiety significantly decreased from pre-competition 29.3 ± 3.2 to post-competition 23.7 ± 2.9 . A very strong negative correlation ($r = -0.68$, $p = 0.001$) was found between pre-competition anxiety and performance. Likewise, a medium negative correlation ($r = -0.52$, $p = 0.020$) was found between post-competition anxiety and performance. Results indicate that more competitive anxiety leads to worse badminton performance. When athletes are taught to use relaxation, imagery, emotional regulation, and self-confidence techniques as a part of regular coaching, they may be able to perform under pressure.

Keywords — badminton, competitive anxiety, SCAT, sport performance, self-confidence.

I. INTRODUCTION

The effectiveness of modern sport performance currently depends on the synergistic application of the above disciplines. Anxiety is crucial in sport psychology as it can affect concentration, confidence, emotional control, decision-making,

and the execution of learned motor skills under pressure [7], [8].

Competitive anxiety denotes the mental and emotional response that an athlete experiences when he/she perceives an event as threatening. Symptoms one may experience include tension, worry and fear of failure. It can also occur due to reductions in confidence and autonomic arousal. Competitive anxiety is more of a sports-specific construct that can influence how an athlete interprets competition (Martens, Vealey and Burton, 1990) [1]. Contemporary models further suggest that not only the intensity of anxiety but also the athlete's interpretation and regulation of that anxiety determine performance [9], [10].

Badminton requires a lot of speed, agility, anticipation, visual focus, quick decisions, and emotional stability. Rallies are so rapid that small technical errors can determine the outcome of the match. Excessive anxiety, on the other hand, can compromise timing and coordination of movements and tactical judgment and shot selection. Research studies through competitive sport have generally presented an inverse relationship between poorly regulated anxiety and performance [2]–[6].

The increasing use of sport psychology is well recognized; however, little evidence is available regarding the relationship between competitive anxiety and objectively obtained performance scores among Indian intercollegiate badminton players. The current research therefore explored the link between pre-competition anxiety, post-competition anxiety, and performance of male badminton players aged 18–23 years. It was hypothesized that there

exists a significant negative association between competitive anxiety and performance.

II. RELATED LITERATURE

According to research by Martens et al., competitive anxiety is a sport-specific psychological quality with reliable measurement [1]. Mottaghi et al. subsequently reported that the relationship between competitive anxiety and performance is meaningful and of practical importance to athletes and coaches [2].

Comparative studies also show that anxiety levels differ across sports, levels of competition, and player groups. Rastogi and Katiyar evaluated sport competition anxiety among college players [3] and Biswas et al. studied competitive anxiety among national players of cricket and shuttle [5]. Uncontrolled anxiety can have a negative impact on one's attention, confidence and athletic performance [4], with a difference in effect for male players compared to female badminton players [6].

The literature on applied sport psychology suggests that athletes enhance through psychological skills training their capacity for interpreting arousal more constructively and regulating cognitive and somatic symptoms [7], [8]. According to [9] and [10], performance anxiety can happen with 3D and directional approaches, and anxiety may be facilitative or debilitative according to confidence, perceived control, and interpretation of the situation. Theoretical basis for viewing anxiety and badminton competition before and after the opponent's show.

III. METHODOLOGY

A. Research Design and Participants: The design does describe correlational research. The male badminton players selected as the sample for the study were taken from Seth Girdhari Lal Bihani S.D. P.G. College, Sri Ganganagar, Rajasthan. The players' ages ranged from 18 to 23 years. Using simple random sampling, participants were selected from the players participating in inter-collegiate

tournaments for the academic sessions 2024-25 and 2025-26.

B. Instrument: Competitive anxiety was measured using the Sport Competition Anxiety Test (SCAT) developed by Rainer Martens [1]. The instrument contains 15 items, of which 10 contribute to the anxiety score and five act as filler items intended to reduce response bias. The scored items were 2, 3, 5, 6, 8, 9, 11, 12, 14, and 15. Higher total scores indicated greater competitive anxiety.

C. Data-Collection Procedure: The researcher personally administered the questionnaire at the competition venue. Participants were instructed to answer independently and honestly, with confidentiality and anonymity ensured. Assessment of anxiety was done right before and after the match. The performance scores were determined from the official match results using the scoring system used in the study.

D. Statistical Analysis: Descriptive statistics for pre-competition, post-competition anxiety and performance were calculated. Pearson's product-moment correlation was employed to assess the relationship between anxiety and performance. Statistical significance was evaluated at $\alpha = 0.05$.

IV. RESULTS

TABLE I
DESCRIPTIVE STATISTICS OF
COMPETITIVE ANXIETY AND
PERFORMANCE

Variable	N	Mean	SD	Range
Pre-comp. anxiety	20	29.3	3.2	24–34
Post-comp. anxiety	20	23.7	2.9	19–29
Performance score	20	75.2	5.8	66–85

As shown in Table I, mean pre-competition anxiety was 29.3 ± 3.2 , whereas mean post-competition anxiety was 23.7 ± 2.9 . This represents a mean reduction of 5.6 points, or approximately 19.1% relative to the pre-competition mean. Performance

scores ranged from 66 to 85, with a mean of 75.2 ± 5.8 .

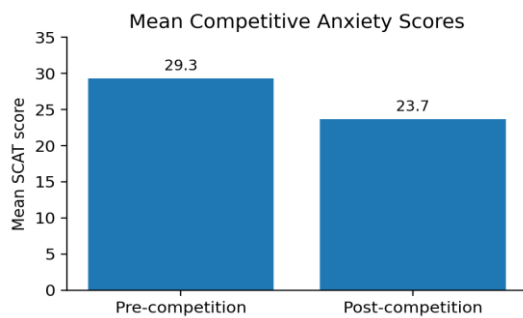


Fig. 1. Mean pre-competition and post-competition anxiety scores.

TABLE II
PEARSON CORRELATIONS BETWEEN ANXIETY AND PERFORMANCE

Relationship	r	p	Decision
Pre-anxiety–performance	−0.68	0.001	Significant
Post-anxiety–performance	−0.52	0.020	Significant

Table II shows statistically significant negative correlations between competitive anxiety and performance. Pre-competition anxiety had a strong negative relationship with performance ($r = -0.68$, $p = 0.001$), while post-competition anxiety had a moderate negative relationship ($r = -0.52$, $p = 0.020$). Therefore, the null hypothesis of no significant relationship was rejected. The magnitude of the pre-competition correlation indicates that anxiety experienced before the match was more strongly associated with performance than anxiety measured after participation.

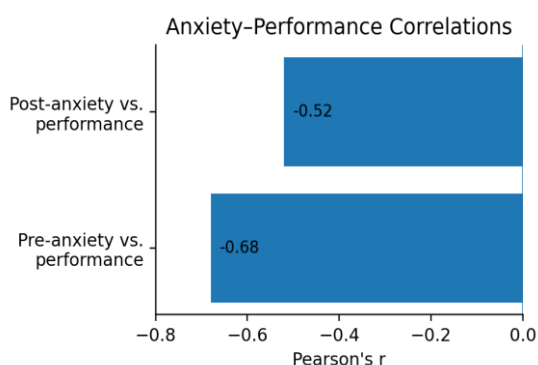


Fig. 2. Correlation coefficients for competitive anxiety and badminton performance.

V. DISCUSSION

Results indicate competitive anxiety has an inverse relationship with badminton performance. Players with greater anxiety scores tended to get lower performance scores. The result corresponds to the finding that a high level of cognitive worry and somatic arousal decreases attentional control, confidence, coordination, and decision quality when competing [2], [4], [7], [9]. In badminton, these effects may emerge as mistimed strokes, poor tactical decisions, hesitation, or a greater occurrence of unforced errors.

The stronger association identified with pre-competition anxiety stresses upon pre-match timing. Before play takes place, one's attentional resources may become consumed with worry of anticipation, fear of failure, and uncertainty with the opponent. The anxiety directional approaches indicate that if an athlete interprets one's arousal as controllable or a performance enhancer, one will cope better than an athlete who interprets those same symptoms as threatening [10].

The decrease of post-competition anxiety mean should not be interpreted as evidence that competition per se lowers trait anxiety. Rather it outlines the immediate difference between the two assessment occasions in this sample. Although match completion may clarify uncertainty, post-match reactions can also emanate from the outcome, satisfaction, fatigue and hindsight.

VI. LIMITATIONS

The limited sample (only male and comprised a single college) restricts the study. The correlational design does not imply causality, whereas the performance-score calculation was unique to the competition procedure used in this study. The study did not control for potential confounders, including playing experience, skill level, opponent strength, match importance, sleep, and prior psychological training. Further research should utilize larger and more diverse samples, report instrument reliability,

standardize performance measures, and apply repeated measures or multivariate models.

VII. CONCLUSION

The selected intercollegiate male players have a significant negative association between competitive anxiety and badminton performance. Before competition, the association was stronger than after competition, indicating that psychological readiness before the match may be key. This result supports the inclusion of anxiety management, emotion regulation, and confidence-building strategies in badminton coaching.

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A Comparative Study of Motor Fitness Components of Kho-Kho and Kabaddi Players

¹Mr. Pritam Malik, ²Dr. Chanderkant Dhiman

¹Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda (PB)

²Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda (PB)

Email Id: ¹pritam.malik623@gmail.com, ²drchanderkantdhiman172212@gku.ac.in

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Abstract—Motor fitness is a vital element in competitive sports and, hence, in enhancing an athlete's aerobic power. Games like Kho-Kho and Kabaddi are indigenous sports played in India that combine human abilities such as speed, agility, strength, endurance, flexibility, and coordination. Although both sports share commonalities, they differ in movement, physiological demands, and tactical play, and these differences can affect players' motor fitness characteristics in the two sports. The present study is designed to evaluate Kho-Kho and Kabaddi players on selected motor fitness parameters and to compare the two in this context. Sixty (30 Kho-Kho and 30 Kabaddi players, age 18-25) were selected for the study. Each athlete performed a series of standardized motor tests for the purpose of assessing speed, agility, endurance, flexibility and explosive power. Descriptive statistics were used, and an independent-samples t-test was performed to assess significant differences between the groups. The results indicated significant differences among sports with regard to specific motor fitness components, due to their differing physical requirements. The information presented in this study will benefit coaches, trainers, and physical educators in developing sport-specific conditioning regimens and improving elite athletes.

Keywords — Physical Education, Motor Fitness, Kho-Kho, Kabaddi, Sports Performance, Agility, Endurance, Speed, Strength, Flexibility, Explosive Power, Comparative Analysis, Sports Science.

I. INTRODUCTION

Physical fitness is a key factor in sports performance and an essential influence on an athlete's efficiency in training and competition. Physical fitness is a key determinant in movement efficiency, skill production, injury prevention and athletic success. Motor fitness, among all physical fitness components, is one of the most important factors affecting the performance of competitive sports [1]. Motor Fitness – The ability of the person to engage in physical activity involving speed, agility, strength, endurance, flexibility, balance, coordination and power. Successful high-quality athletes can respond to game conditions, perform their activities under fatigue, and act sport-specifically more effectively [2]. The wisdom of indigenous games in India is vast and holds great importance in both physical development/education and cultural heritage. Of these sports, Kho-Kho and Kabaddi are the two most popular and fiercely played sports in the country. The two games are physically demanding, and both have a high strategic element, but their physiological and action requirements are very different. It is really important to understand these differences to develop effective training initiatives and improve sports performance Effectiveness [3].

Kho-Kho is a game of tagging, played at a very fast pace and requiring players to react quickly, accelerate, and sprint. Chasers have to be quick, agile and have good balance and coordination. The game requires a great deal of agility, quickness,

reaction time and neuromuscular coordination. In Kho-Kho, players routinely perform running, dodging, and turning movements, so agility is one of the most important factors determining successful performance [4]. Kabaddi is an anaerobic, endurance-based, contact-based team game that requires physical strength, tactical intelligence, and the ability to make quick decisions. Players need to use explosive actions during raids or defensive situations, negotiate physically, and control their bodies under stress. This sport requires a high level of muscular strength, power, anaerobic fitness, and muscular endurance. Besides, being physically and mentally ready for tactical operations such as raid, block, hold, and escape [5].

Motor fitness is considered a fundamental factor in sports performance, encompassing speed, agility, strength, endurance, flexibility, and power. Many studies have examined the effects of these components on performance across various sports. These are the indigenous sports in India that require a high amount of motor fitness, for example, Kho-Kho, kabaddi and so on [7]. Recent research has stressed the need to evaluate motor fitness characteristics, determine the physical demands of a sport, and design a training plan that matches the sport's requirements. Comparative studies comparing players of Kho-Kho and Kabaddi have reported differences in agility, strength, endurance, and flexibility due to differences in the game actions, physiological requirements, etc., of both games [8].

A comparative study by Varsha Gautam (2022) involving 40 university-level Kho-Kho and Kabaddi players assessed motor fitness variables (speed, agility, endurance, and strength). There were significant differences in agility, endurance, and strength between the two groups, but no significant difference in speed (independent-samples t test). Kabaddi players proved to be stronger and more endurance, while Kho-Kho players proved to be

more agile [9]. A comparative evaluation of physical fitness variables of female Kho-Kho and Kabaddi players was published in 2024. The findings indicated that Kho-Kho players possessed better agility, speed, and flexibility than Kabaddi players due to the involvement of chasing and the fast-paced nature of Kho-Kho [10].

To compare motor fitness components between Kho-Kho and Kabaddi athletes, Chikkagoudra and Kellur (2026) conducted a study and found significant differences in the selected performance variables. They said the special physiological demands of the two sports give rise to differences in motor fitness profiles.

Physiology of Muscle Cell – In recent years, a growing area of interest in sports has focused on muscle cell physiology, resulting in physical preparation that optimizes performance. The results revealed that structured training interventions significantly improved physical fitness, physiological adaptations, and sports participation performance of Kabaddi players (González-Devesa et al. 2026). It is indicative of the development of a systematic training program to improve the fitness and physiological adaptations of Kabaddi players.

Many studies have been conducted separately on the physiological responses and physical fitness of Kho-Kho and Kabaddi players. Few studies, however, have compared them.

A majority of studies have concentrated on fitness variables and/or a restricted athlete population. It is essential to do a comparative study of the different components of motor fitness between Kho-Kho and Kabaddi players of different sports organizations so that we can know the demands of their respective sports and ground their training practices on evidence [12].

A. Research Gap: Certain research has focused on the motor fitness of individual sports, but not much has been conducted to compare the motor fitness of Kho-Kho & Kabaddi Players. Past studies generally

focused on elite athletes in a single sport and/or on specific fitness factors. Without detailed and high-quality analysis, the comparison of the components of motor fitness is possible due to differences in the nature of the game, playing style, as well as physiological load. This study can be highly beneficial for identifying and determining the specific fitness needs of the sport, which will further help coaches and trainers design training programs that focus on these needs [6].

II. RESEARCH METHODOLOGY

A. Research Design: The present study was descriptive and comparative, examining and comparing the motor fitness components of both Kho-Kho and Kabaddi players. This was deemed suitable because it would enable the researcher to establish differences in the physical fitness characteristics between two groups, and no variables would need to be altered. This study was designed to determine whether significant differences existed between the two groups of athletes and to evaluate selected motor fitness parameters [13].

B. Participants: In total, 100 male players were assessed. The sample was selected from Kho-Kho and Kabaddi players at 50 colleges, universities, and sports academies. The participants were individuals aged 18-25 with at least 2 years of competitive playing experience in their sport(s). At the time of data collection, all participants were physically fit and engaged in physical training, and competition regularly.

C. Sampling Technique: Purposive sampling was used to select the participants. This method was used since people with specific characteristics (active participation and experience in competitive Kho-Kho or Kabaddi) were required for the study. The sole criterion for selecting the players was that they were part of the target population and deemed suitable for measuring their sport-specific motor fitness characteristics.



Figure 1. Research Methodology Flowchart

D. Motor Fitness Variables: Motor fitness is the ability required for good sports performance. The motor fitness variables that were selected for assessment were based on the physiological needs of Kho-Kho and Kabaddi:

TABLE I

MOTOR FITNESS VARIABLES AND TESTS

Variable	Test Used
Speed	50 Meter Dash
Agility	4 × 10 Shuttle Run
Explosive Power	Standing Broad Jump
Flexibility	Sit and Reach Test
Strength	Push-Up Test
Endurance	600 Meter Run

E. Fitness Tests Employed: The motor fitness test was used to evaluate the selected variables, and it was standardized. They are generally suitable for sports science studies and are reliable indicators of physical performance.

• **Speed Test:** 50 Meter Dash: To measure speed,

the 50 Meter Dash was employed. All participants were asked to run 50m as fast as possible. A stopwatch was used to measure the time, in seconds, required to complete the distance.

- **Agility Test:** 4 X 10m Shuttle Run: 4 × 10 Meter Shuttle Run Test was used to determine agility. The participants would run in a square formation from line to line, 10 m apart, and changing direction quickly. The time necessary to complete the test was noted.
- **Explosive Power Test:** Standing Broad Jump: Lower-body explosive power was determined using the Standing Broad Jump Test. Participants started from a standing position and jumped forward; the furthest distance jumped was recorded in centimeters.
- **Flexibility Test:** Sit and Reach Test: Sit and Reach Test was used to measure flexibility. With their legs fully straightened, participants sat on the floor, reaching as far as possible. All tubing measurements were taken to the maximum reach (cm).
- **Strength Test: Push-up Test:** Strength and muscle capability assessment was conducted in terms of the Push-Up Test. Participants did as many pushups as they could get right without resting. The total number completed was scored as the final score.
- **Endurance Test:** 600 Meter Run: The 600m Run Test was used to assess cardiovascular endurance. The try was a 600-meter sprint for the lowest possible time. The times (in minutes and seconds) were recorded.

F. Data Collection Procedure: The data collection method was adopted as acceptable conditions in order to guarantee that the facts are valid and reliable.

Permission was obtained from the institutions/sports authorities before the test. The participants were explicitly informed about the purpose of this study, and they agreed to participate and provided consent.

All fitness assessments took place at a standard sports field and in ideal climatic conditions. Prior to the start of the testing session, a warm-up was conducted, including light jogging, stretching, and mobility drills for 10-15 minutes. The goal of the warm-up was to prepare your body for action. It was also to reduce the chances of you getting injured.

Participants were provided with specific information on the tests. Demonstration exercises of all fitness tests were performed to ensure uniformity of understanding. All tests were given one after the other, and sufficient rest was allowed between repeated tests to prevent fatigue effects.

After every test, an assessment was done immediately with assessment sheets. To avoid measurement errors, they were checked. All participants must do their utmost for the test.

Safeguards were observed during data collection. Sufficient water and first aid were provided, and appropriate staff were on hand. Any participant who found any discomfort or injury was prohibited from proceeding with further testing.

G. Statistical Analysis: All the gathered data were arranged, tabulated and analysed by suitable statistical methods. Descriptive (frequencies, percentages, etc.) and inferential (Means, Mann-Whitney Test, etc.) statistics were used to summarize the performance characteristics of the two groups and to identify significant differences between them.

The following statistics were used:

- **Mean:** Arithmetic mean was computed for each motor fitness variable to provide an average of each.

$$\bar{x} = \frac{\sum_{i=1}^N X_i}{N}$$

Where:

- $\bar{x}$ = Mean score
- $\sum X_i$ = Sum of observations
- N = Total number of observations

- **Standard Deviation:** Standard deviation was computed to determine the variation and the extent to which scores spread out from the average (mean).

$$SD = \frac{\sqrt{\sum_{i=1}^N (X_i - \bar{x})^2}}{N}$$

Where:

- SD = Standard deviation
- X = Individual score
- $\bar{x}$ = Mean score
- N = Number of observations

- **Independent Sample t-Test:** Thus, the averaged values for each motor fitness variable for both Kho-Kho and Kabaddi players were compared using an independent sample t-test.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(\frac{SD_1^2}{n_1}\right) + \left(\frac{SD_2^2}{n_2}\right)}}$$

Where:

- $\bar{x}_1$ = Mean score of Kho-Kho players
 - $\bar{x}_2$ = Mean score of Kabaddi players
 - SD₁ = Standard deviation of Kho-Kho players
 - SD₂ = Standard deviation of Kabaddi players
 - n₁ = Number of Kho-Kho players
 - n₂ = Number of Kabaddi players
- **Level of Significance:** The criterion of significance for all of the statistical tests was set at:
p<0.05

A value of p < 0.05 was taken as significant, indicating the difference between the motor fitness characteristics of Kho-Kho and Kabaddi players was meaningful.

III. RESULTS ANALYSIS & DISCUSSION

Descriptive and inferential Statistical techniques were used to analyses the collected data. The means and SDs for each of the motor fitness variables were determined. An independent sample t-test was used to identify the significant difference between Kho-Kho players and Kabaddi player at 5% level of significance.

- **Interpretation:** The findings showed that both the 50m running and Kho-Kho players has traversed the said distance in lesser time as compared to the Kabaddi players. This implies that the Kho-Kho athletes are able to perform their game faster.

TABLE II
COMPARISON OF SPEED PERFORMANCE
(50 METER DASH)

Group	Mean (sec)	SD	t-value	p-value
Kho-Kho Players	7.12	0.38	3.84	<0.05
Kabaddi Players	7.45	0.41	-----	-----

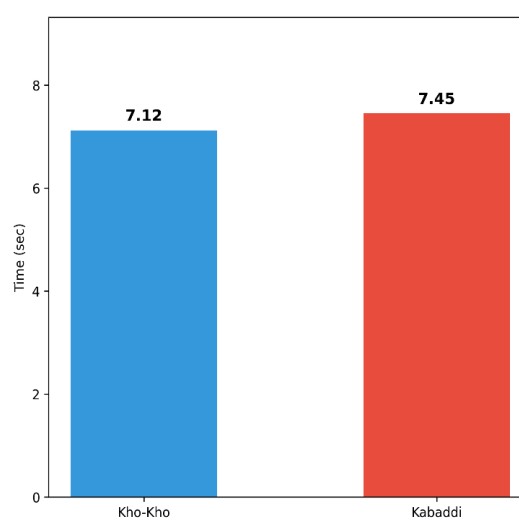


Figure 2. Comparative Speed Performance

- **Interpretation:** Kho-Kho players had a significantly higher level of agility performance than Kabaddi players. The game moves at a fast pace and often features rapid shifts in emphasis; these features may further boost agility.

TABLE III
COMPARISON OF AGILITY
PERFORMANCE (4 × 10 M SHUTTLE RUN)

Group	Mean (sec)	SD	t-value	p-value
Kho-Kho Players	10.21	0.52	4.26	<0.05
Kabaddi Players	10.86	0.57	-----	-----

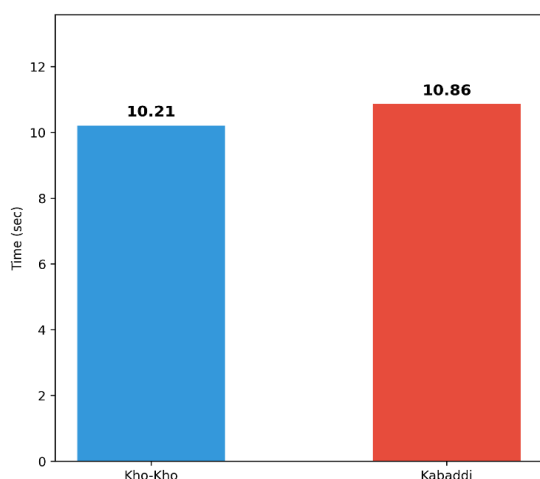
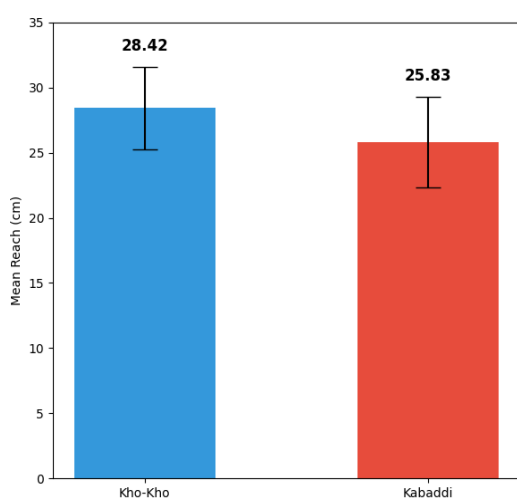


Figure 3. Comparative Agility Performance

•**Interpretation:** Kho-Kho players had also demonstrated significant flexibility as compared to Kabaddi players which is an inference of better joint mobility and movement efficiency in Kho-Kho players.

TABLE IV
COMPARISON OF FLEXIBILITY
PERFORMANCE (SIT AND REACH TEST)

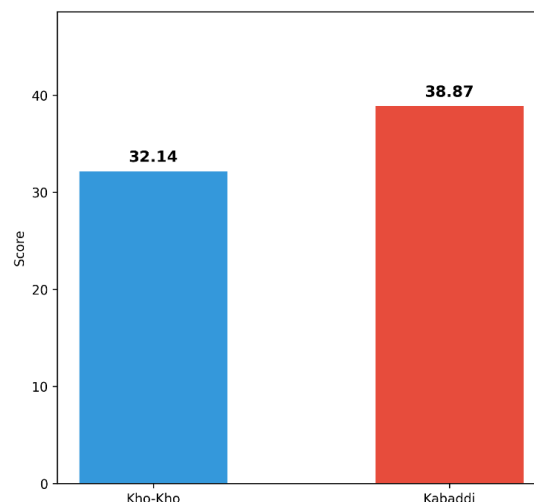
Group	Mean	SD	t-value	p-value
Kho-Kho Players	28.42	3.14	2.71	<0.05
Kabaddi Players	25.83	3.48	-----	-----



•**Interpretation:** The strength score of Kabaddi players was much higher than that of Kho-Kho players. Since Kabaddi is a contact sport, the players' muscles are likely more developed as a result.

TABLE V
COMPARISON OF MUSCULAR STRENGTH
(PUSH-UP TEST).

Group	Mean	SD	t-value	p-value
Kho-Kho Players	32.14	4.25	4.63	<0.05
Kabaddi Players	38.87	4.68	-----	-----



•**Interpretation:** The repeated endurance phase was done by Kho-Kho players in less time as compared to Kabaddi players, thus showing better cardiovascular endurance.

TABLE VI
COMPARISON OF CARDIOVASCULAR
ENDURANCE (600 M RUN)

Group	Mean	SD	t-value	p-value
Kho-Kho Players	2.08	0.16	3.11	<0.05
Kabaddi Players	2.21	0.18	-----	-----

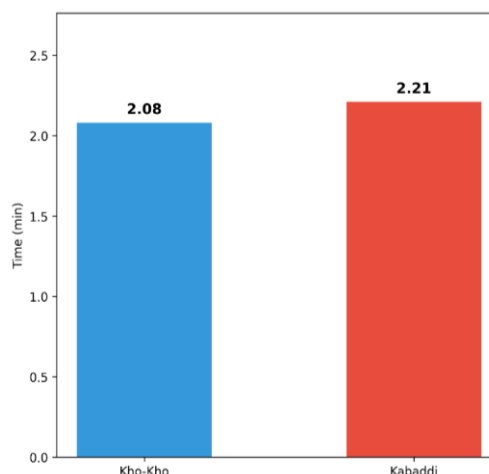


Figure 6. Comparative Endurance Performance

•**Interpretation:** The standing broad jump distances of kabaddi players were significantly higher than the duration of their action compared to other players, suggesting that they have more explosive capacity in their lower body, which can be utilized in playing the game.

TABLE VII
COMPARISON OF EXPLOSIVE POWER
(STANDING BROAD JUMP)

Group	Mean (cm)	SD	t-value	p-value
Kho-Kho Players	208.5	12.4	3.92	<0.05
Kabaddi Players	221.8	14.1	----	----

• **Overall Comparative Analysis:** The statistical difference showed that there is a significant difference between the players of the two games, Kho-Kho and Kabaddi, in all selected MFVs. Kho-Kho players showed greater speed, agility, flexibility, and cardiovascular endurance than Kabaddi players, who showed greater muscular strength and explosive power.

In the present study, the motor fitness components of Kho-Kho and Kabaddi players were compared, and significant differences were found between the two groups. The results indicate that specific sports elicit distinct fitness profiles due to the distinct physiological and movement demands they impose on the body.

• **Speed Performance:** Kho-Kho players showed their speed performance with significant superiority as compared to Kabaddi players. This result could be explained due to the repetitive nature of Kho-Kho which consist of numerous sprinting, chasing opponents and acceleration movements in short bursts. Players execute fast movements all game long, so they can improve their sprinting skills and neuromuscular efficiency.

• **Agility Performance:** The results revealed that Kho-Kho players had better agility. Being agile is an essential part of Kho-Kho, as players often have

to evade opponents and quickly respond to the changing dynamics and situations while shifting their body movement. Multi-directional movement improves agility performance through continuous exposure to this type of movement, which helps develop coordination, balance, and reaction speed.

• **Flexibility Performance:** The score of flexibility was greater for Kho-Kho players as compared to Kabaddi players. This frequent motion of bending, turning, stretching, and evasion throughout the game allows for greater joint mobility and muscle flexibility. New flexibility benefits may even decrease the likelihood of injury and increase movement efficiency in competition.

IV. CONCLUSION

The present study has been undertaken to compare the motor fitness components of Kho-Kho Man Players and Kabaddi Man Players and to identify any sport-specific differences in the selected motor fitness components. The analysis results indicated substantial differences between the two groups across many of the motor fitness parameters studied. This shows that the sports channels' physiological and movement requirements affect the development of motor fitness attributes.

The Kho-Kho players were found to be faster than the other players in terms of gameplay speed, as well as in agility, flexibility, and cardio-respiratory endurance. The advantages of these features can be seen in Kho-Kho's fast, continuous movement towards and around blocks, chasing plays, and consistent movement patterns. On the other hand, better muscle strength and explosive power were exhibited by kabaddi team players due to the presence of confrontation (tackles) and resistance (opponent) in raids, as well as anaerobic (high-intensity) activities.

Statistical analysis revealed that the differences were significant at the 0.05 level. Hence, the motor fitness profiles of Kho-Kho and Kabaddi players differ, and

vice versa. The study demonstrates the impact of sport-specific physical conditioning and good programs on sport performance: implications for practitioners.

From the coach's perspective, this information will be useful for coaches, trainers, sport scientists, and physical educators. A coach of Kho-Kho Players should develop agility, sprinting, flexibility, and aerobic conditioning. On the other hand, Kabaddi coaches must focus on developing strength, power, resistance, and aerobic training to improve the physical aspect of Kabaddi.

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Relationship Between Competitive Anxiety and Performance in University Rugby Players

¹Anishka Singh, ²Dr. Ravi Kumar

¹ Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

² Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India

Email Id: ¹ rajputvaani2004@gmail.com, ² ravikumar.gahalawat@gmail.com

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Abstract— This study examined competitive anxiety and its relationship with selected rugby skill-performance measures among university players. Twenty inter-university rugby players from Panjab University, Chandigarh (10 males and 10 females; 18–25 years) were selected through non-probability sampling. Competitive anxiety was assessed with the Sport Competition Anxiety Test (SCAT), and performance was evaluated through catching, tackling, and passing measures. Descriptive statistics, an independent-samples *t*-test, and Pearson product-moment correlations were used at the 0.05 significance level. Female players reported a higher mean SCAT score than male players (19.0 versus 16.8), but the difference was not statistically significant, $t(18) = -1.48$, $p = .155$. Competitive anxiety was negatively related to catching ($r = -0.314$), tackling ($r = -0.129$), and passing ($r = -0.098$); however, none of these relationships was statistically significant. The performance skills were positively interrelated, particularly tackling and passing ($r = 0.921$, $p < .001$). The findings indicate that anxiety existed among the players but did not significantly explain the selected skill-performance outcomes in this small sample.

Keywords— competitive anxiety, rugby, SCAT, sport performance, university players.

I. INTRODUCTION

The athlete's performance in sports varies on his physical preparation, technical skills, tactical competence and psychological condition. At more advanced levels, factors such as confidence, concentration, motivation, emotional control and

regulation of pressure can affect whether an athlete executes learned skills successfully. Psychological preparation is considered a part of the training and not an add on, so the research in rugby and all sport psychology looks at it [2], [3].

Before taking part in any competition an athlete may experience worries and fears and this is termed as competitive anxiety. Anxiety can manifest in a variety of ways. Such as negative thought patterns through which a person experiences fear of failure. Also, a somatic manifestation may include an elevation in heart rate, sweating, muscular tension, and interrupted breathing. A manageable level of arousal helps you to be alert. If a person is too anxious, it can affect his attention, coordination, decision-making, and confidence level [4]–[6].

Rugby is strenuous and demands catching, tackling, and passing on the run while under social pressure. Players have to think tactically while dealing with physical contact, crowd expectations, selection pressure, and error fear. Earlier researches in rugby have linked competitive anxiety and psychological-skill use with performances-related responses. Thus, it is pertinent to evaluate them in the university context [1], [2].

Within India, literature surrounding university level rugby players remains limited, especially among mixed-gender samples. As such, the present investigation determined competitive anxiety of male and female rugby players, and its relationship with selected rugby skill-performance measures.

II. OBJECTIVES & RATIONALE

The study pursued the following objectives:

- A. To assess competitive anxiety among male and female university rugby players using the SCAT;
- B. To compare competitive anxiety between male and female players; and
- C. To examine the relationship between competitive anxiety and catching, tackling, and passing performance.

The rationale was that rugby combines technical execution with intense physical contact and time pressure. Understanding whether anxiety is associated with skill performance may assist coaches and sport psychologists in deciding when anxiety-management training is warranted [1], [2].

III. METHODOLOGY

A. Research Design and Participants

A descriptive correlational design was adopted. The sample consisted of 20 inter-university rugby players from Panjab University, Chandigarh: 10 male and 10 female players aged 18–25 years. Participants were selected through non-probability sampling based on availability and willingness. Players with at least two years of playing experience were included, whereas injured players were excluded. Informed consent was obtained and confidentiality was maintained.

B. Instruments and Procedure

Competitive anxiety was measured with the Sport Competition Anxiety Test (SCAT) developed by Martens [7]. Rugby performance was represented by scores for catching, tackling, and passing obtained through the Rugby Skill Performance Test used in the original study. Questionnaires and performance tests were administered in a standardized manner.

C. Statistical Analysis

Data were summarized using the mean, median, standard deviation (SD), and standard error (SE). An independent-samples t-test compared male and female SCAT scores. Pearson product-moment correlation examined relationships among anxiety and rugby skills. Statistical significance was evaluated at $\alpha = 0.05$.

IV. RESULTS

TABLE I
DESCRIPTIVE STATISTICS FOR SCAT
SCORES

Group	Mean	Median	SD	SE
Male (n=10)	16.8	16.0	4.18	1.32
Female (n=10)	19.0	19.0	2.11	0.667

As shown in Table I, female players recorded a higher mean competitive-anxiety score ($M = 19.0$, $SD = 2.11$) than male players ($M = 16.8$, $SD = 4.18$). The descriptive difference was 2.20 SCAT points.

TABLE II
INDEPENDENT-SAMPLES T-TEST FOR
SCAT SCORES

t (df)	p	Mean Diff.	SE Diff.
-1.48 (18)	.155	-2.20	1.48

The gender difference was not statistically significant, $t(18) = -1.48$, $p = .155$. Thus, the observed higher mean among female players cannot be interpreted as reliable evidence of a gender difference in the population represented by this sample.

TABLE III
PEARSON CORRELATIONS AMONG SCAT
AND RUGBY SKILLS

Variables	r	df	p
SCAT–Catching	-0.314	18	.178
SCAT–Tackling	-0.129	18	.588
SCAT–Passing	-0.098	18	.681
Catching–Tackling	0.681	18	<.001
Catching–Passing	0.603	18	.005
Tackling–Passing	0.921	18	<.001

The significant negative correlations identified between competitive anxiety and catching, tackling and passing were weak-to-moderate and statistically non-significant. Conversely, there were positives connections between the rugby skill variables. The correlation between tackling and passing was found to be the highest ($r = 0.921$, $p < .001$).

V. DISCUSSION

Results reveal that female players reported slightly more competitive anxiety than male players, but this

difference was not statistically significant. Given the small sample size of 10 participants per group and the use of non-probability sampling, this finding should be interpreted with caution.

The SCAT correlation results were negative, reflecting higher anxiety with lower skill-performance scores. Nonetheless, the findings did not convincingly demonstrate any significant influence of competitive anxiety on catching, tackling, or passing in this sample. This pattern is consistent with findings in the literature, indicating that the relationship between anxiety and performance varies depending on skill level, psychological interpretation, mental toughness, and the competitiveness context [1], [2], [4]–[6].

The performance of rugby players in catching, tackling, and passing is strongly correlated. Namely, those who perform well in one skill tend to perform well in the other skills. The implication for coaches is that anxiety is not to be dismissed but something that should be trained psychologically and assessed technically. Where disruptive anxiety responses are evident in individual players, relaxation, breathing control, imagery, goal setting and confidence-building may be useful [2], [4].

VI. LIMITATIONS

Due to its small sample size, a single university, the use of non-probability sampling and self-reported anxiety, the study was limited. The variables of education, culture, residential background, family support, financial conditions, playing position, previous injuries, experience, strength of opponent, and present coping measures were not taken into consideration. Causal conclusions cannot be drawn as the designs are often cross-sectional.

VII. CONCLUSION

No significant differences in competitive anxiety were found between male and female rugby players. Competitive anxiety had a negative relationship with catching, tackling and passing (non-significant). As a result, competitive anxiety does not have

significant control on the performance of skilled rugby players. Nonetheless, overseeing and controlling anxiety remains pertinent because psychological preparedness may affect athletes differently depending on conditions and level of competition.

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To Develop Training Program for Improvement of Libero Volleyball Players of Rajasthan

¹ Praveen Bugalia, ² Dr. Rajwinder Kaur

¹M.P.Ed., Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India.

²Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda.

Email Id: ¹p7023545677@gmail.com, ²rajwinderkaur0567@gmail.com

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Abstract— The libero position was introduced in volleyball in the year 1998. It is essential for the organization of defense and efficiency in serve reception. However, systematic, evidence-based, position-specific training programs for libero players are not available at regional levels in India, particularly in the state of Rajasthan. The present study aimed to develop and evaluate the efficacy of 4-week libero specific training program on biomotor abilities and position-specific technical skills of Rajasthan state-level and district-level libero volleyball players. They used a single-group experimental design. The study involved thirty male libero volleyball players ($n = 30$; mean age: 21.47 ± 2.13 years; mean height: 173.2 ± 5.4 cm; mean body mass: 68.5 ± 6.8 kg; mean playing experience: 4.8 ± 1.9 years), who were purposively selected from Rajasthan. The programming for the libero-specific training that was applied in the study utilized periodization principles (Bompa & Haff, 2009) and also drew on the force-velocity spectrum concept which governs human movement (Haff & Nimphius, 2012). It consisted of five sessions a week for four weeks each and was divided into Foundation, Development and Peaking phases. The main aims of the training were to improve the reactive strength, explosive power, agility, forearm passing accuracy and reactive digging efficacy of the athletes.

Normality of the data was tested using Kolmogorov-Smirnov tests, while homogeneity of variance was assessed via Levine's test. The analysis of the results indicated statistically significant improvements in

all five dependent variables. The countermovement jump (CMJ) improved by 3.87 cm (10.2%), $t = 12.45$, $p < 0.001$, $d = 2.27$. The reactive strength index (RSI) improved by 0.27 (14.8%), $t = 10.82$, $p < 0.001$, $d = 1.98$. The pro-agility shuttle time improved by -0.35 seconds (6.4%), $t = -11.24$, $p < 0.001$, $d = 2.05$. The forearm passing accuracy improved by 10.40% (15.3%), $t = 14.82$, $p < 0.001$, $d = 2.71$. Finally, the reactive digging efficacy improved by 11.47% (18.2%), $t = 13.56$, $p < 0.001$, $d = 2.48$. All Cohen's d values were greater than 1.98, indicating very large practical effects. All five proposed research hypotheses were accepted. Backed by scientific proof, the research introduces a values-driven training program for position-specific libero, which through short-duration training, can induce superior performance changes in physical and technical skills of an inter-school libero. The results have significant coach education and libero development implications in the state of Rajasthan.

Keywords— Libero, Volleyball, Position-Specific Training, Rajasthan, Reactive Strength Index, Countermovement Jump, Passing Accuracy, Digging Efficacy, Periodization.

I. INTRODUCTION

Volleyball is one of the most played team sports worldwide (estimated 800 million participants in 220 countries) which was created in 1895 (FIVB, 2021). The libero player introduced in 1998 has probably been the most transformational rule change of the modern era in the game of volleyball. The original text states that this player was introduced to

prolong rallies and improve defensive quality, as well as to counterbalance the overwhelming competitive advantage that offensive spikers had gotten (FIVB, 1999). Which basically means that these players were introduced to balance the growing dominance that attacking spikers have acquired. In modern volleyball, the libero touches the ball on more than 45% of the contacts per set, working as the key for serve reception efficiency, defence organisation and transition offence (Altavilla & Raiola, 2019).

The physiological and technical requirements of the libero position are different from those of all the volleyball positions. According to Match analysis of positional play (Sheppard et al. (2009), liberos perform 42% more defensive actions in each set than front row players, cover a significantly greater total distance on the court, while there is considerably shorter mean break between efforts (12.4 ± 3.1 seconds) than an outside hitter (18.7 ± 4.2 seconds). Bobula et al. (2024) conducted a cross-sectional study of 96 competitive players. It was found that a libero's effectiveness was most strongly associated with their eccentric hamstring strength ($r = 0.69$, $p < 0.001$) and ability to maintain low postural positions while lateral shuffling. Liberos had 31% greater eccentric hamstring strength than outside hitters, and 22% faster rate of force development than middle blockers. The physiological demands created by the specific performance requirements of back row players need a highly specialized training stimulus to develop, which conventional back row training programs do not provide.

Rajasthan is a state that represents an active volleyball culture and competitive structures organized through the Rajasthan Volleyball Association (RVA, 2020). Like most states, Rajasthan has many capable attackers and blockers and has consistently produced these kinds of players. However, the lack of any elite-level liberos who can consistently compete at the national level is a worrying thought (Sharma & Gupta, 2018).

According to Choudhary & Meena (2021), typical liberos representing Rajasthan at the state level are found to be deficient in a few areas. These include consistency of forearm passing under float serve. Moreover, they will have a delayed response to cross-court spikes. Furthermore, there will be improper block-defender coordination. Lastly, there will also be a deficiency with composure under competition stress. Coaches in Rajasthan have historically trained liberos with back-row drills meant for all-round or front-row players. Such an approach regularly fails to address the unique biomechanical, perceptual-cognitive, and physiological demands of the position (Krishna & Bhatt, 2019).

This highlights a research gap that warrants attention from scholars and practitioners. Although studies in other countries have profiled elite libero physiology (Sheppard et al., 2009; Bobula et al., 2024), proposed performance evaluation frameworks (Palao et al., 2015; Marra et al., 2019) and examined position-specific training principles (Yılmaz & Ozkan, 2025), almost no study has converted these findings into a complete, periodized training intervention that is validated in a regional, resource-constrained, Indian context. In addition, there is no published study that has systematically assessed the performance deficiencies of the liberos in the state of Rajasthan and developed an evidence-based, context-specific training program to address them. In light of the aforementioned, the present investigation was undertaken to fill this major gap in the literature by developing, implementing, and assessing an empirical position-specific libero training program for the context of Rajasthan's volleyball.

II. REVIEW OF RELATED LITERATURE

A. Physiological Profile and Position-Specific Demands of the Libero

Sheppard et al. (2009) have the first analysis of competition demands and physiological

characteristics of elite male volleyball players in Australia of all positions. According to the study, liberos exhibited better jump ability (reactive strength index, RSI) than middle blockers in volleyball, as well as faster sprint times. This means that the liberos who are essentially defence specialists demonstrated superior performance in terms of explosive strength and speed relative to the middle blockers. These findings lead to the overarching suggestion that the conditioning of a libero should focus on rate of force development (RFD), reactive strength, and repeated-effort capacity rather than maximal strength and this was incorporated into the training programme formulated in the present study.

An understanding of this was expanded by Bobula et al. (2024) through a biomechanical cross-sectional study of 96 competitive volleyball players. Using isokinetic dynamometry, force plate analysis, and three-dimensional motion capture, the authors found that a libero's effectiveness in digging and passing was most strongly correlated with the libero having greater eccentric hamstring strength ($r = 0.69$, $p < 0.001$), rapid rate of force development (22% faster than middle blockers), and ability to maintain low postural positions during lateral shuffling. It is worth noting that liberos had lower concentric quadriceps peak torque compared with front-row attackers, supporting the notion that training for this position should prioritize eccentric strength and sport-specific movement patterns over generalized lower-extremity strengthening. Yilmaz and Ozkan, in 2025, used micro-sensor-LFS technology in 42 elite female players to show that liberos performed 34% more high-intensity directional changes during pre-match warm-ups than the average across all front-row positions, providing evidence to support position-specific warm-up and choice-making.

B. Technical Performance Evaluation of Libero Players

Marra et al. (2019) conducted a longitudinal case study following an elite libero over an 8-month competitive season, documenting improvements in passing efficacy from 68.4% positive passes at season start to 82.1% at peak competition ($p < 0.01$). Crucially, the largest improvements occurred during a six-week mid-season block emphasizing reactive drills and decision-making training, and the strongest predictor of match performance was passing technique maintenance under fatigue — demonstrated by an 11% decline in passing accuracy during third-set versus first-set action. This study provided both the performance benchmarks and the progressive testing protocols (Progressive Bagher Test and Reactive Dig Score) adapted in the present study.

Palao et al. (2015) proposed a comprehensive multi-dimensional evaluation framework for libero performance comprising technical efficiency (passing accuracy, digging success), tactical decision quality, physical performance (court coverage, reactive movement time), and psychological indicators. The framework provided normative data from 120 elite matches and recommended integrated quantitative and qualitative assessment. Gabbett et al. (2010) established in a study of 52 sub-elite female volleyball players that passing and digging skills correlated most strongly with countermovement jump height ($r = 0.61$, $p < 0.01$) and pro-agility shuttle time ($r = 0.58$, $p < 0.01$), and that a combination of these two variables explained 47% of the variance in defensive skill performance — empirical evidence directly informing the selection of CMJ and pro-agility shuttle as primary biomotor outcome measures in the present study.

C. Training Program Design Principles for Libero Development

Bompa and Haff (2009) established the theoretical foundation for the present study's periodized structure through their seminal text on periodization theory. The block periodization model — wherein

each mesocycle emphasizes a limited number of complementary training qualities — was operationalized in the present study as a Foundation Phase (movement efficiency and basic technique), Development Phase (reactive strength and advanced technical skills), and Peaking Phase (competition transfer and maintenance). The force-velocity spectrum framework articulated by Haff and Nimphius (2012), defining a tiered approach from foundational maximal strength through strength-power, power-speed, and speed-strength exercises, was applied to the plyometric and reactive training progressions in the libero program — specifically to develop the lower body reactive power essential for digs and lateral shuffles.

Cormie et al. (2011) provided evidence-based training load guidelines supporting the program design: peak power during ballistic lower body exercises occurs at 30–40% of 1RM; complex training pairing heavy resistance with biomechanically similar ballistic or plyometric movements enhances acute and chronic power adaptations. For the present libero program, these principles translated to complex pairings such as squat jumps followed by reactive lateral bounds in the Development Phase. Altavilla and Raiola (2019), through video analysis of 30 elite FIVB matches, proposed a position-specific training framework comprising five technical pillars (forearm passing, overhead passing, defensive digging, covering, and transition positioning) and three tactical pillars, concluding that libero training must shift from general back-row drills to highly specialized scenario-based training that replicates competitive decision-making demands — a conclusion directly operationalized in the present study's technical training progressions.

III. METHOD & MATERIAL

A. Study Design

The present study employed a pre-test/post-test single-group experimental research design to evaluate the effectiveness of a newly developed

libero-specific training program. All 30 subjects received the experimental training intervention, with standardized assessments administered at baseline (pre-test) and immediately following the 4-week training program (post-test). This design was appropriate for the primary objective of evaluating whether the training program produced significant improvements and is consistent with similar training program development studies in sports science contexts where ethical considerations and practical constraints preclude withholding treatment from a control group.

B. Subjects

Thirty male libero volleyball players ($n = 30$) were purposively selected from Rajasthan. Inclusion criteria required: age 18–25 years; currently representing district-level or state-level teams in competitions sanctioned by the Rajasthan Volleyball Association; minimum of two years of competitive volleyball experience playing exclusively as libero; free from acute or chronic injury at time of testing; available for the entire 4-week training period; and provision of written informed consent. Mean participant characteristics: age 21.47 ± 2.13 years; height 173.2 ± 5.4 cm; body mass 68.5 ± 6.8 kg; playing experience 4.8 ± 1.9 years.

C. Dependent Variables and Assessment Tools

Five dependent variables were assessed at pre-test and post-test: (i) Countermovement Jump height (CMJ, cm) — measured using force plate or validated smartphone jump app; three trials, best recorded; assesses lower body explosive power and stretch-shortening cycle efficiency. (ii) Reactive Strength Index (RSI) — calculated as jump height (cm) $\div$ ground contact time (sec) during a 30-cm drop jump; three trials, mean recorded; assesses neuromuscular efficiency for rapid eccentric-to-concentric transitions. (iii) Pro-Agility Shuttle time (5-10-5, sec) — from three-point stance, sprint 5 yards left, touch, sprint 10 yards right, touch, sprint 5 yards through finish; best of two trials; assesses change-of-direction speed. (iv) Forearm Passing

Accuracy (%) — server delivers 20 standardized serves (float, topspin, underhand mix); libero passes to 50-cm target zone at net; passes rated 0–3; outcome = percentage of perfect passes; adapted from Marra et al. (2019) Progressive Bagher Test.

(v) Reactive Digging Efficacy (%) — 20 standardized spikes delivered by trained server from attack line (cross-court, line, and tip varied); libero starts in defensive base position; successful dig = controlled pass playable by setter; outcome = dig success percentage; adapted from Palao et al. (2015) Reactive Dig Test.

D. Training Program Design

The libero-specific training program, carried out over a 4-week period, was based on periodization (Bompa & Haff, 2009) and force-velocity spectrum theory (Haff & Nimphius, 2012). The parameters of this program suggest five sessions per week, Monday to Friday, each lasting 75–90 minutes. On Saturday and Sunday, it is active recovery or rest. Each session included a standardized dynamic warm-up (light jogging, dynamic stretching, and movement preparation (lateral shuffles, low-posture holds)) that lasted 15 minutes. The booking coach decided on three different components: Component 1 Biomotor training, 15–20 minutes (plyometric, speed, or reactive strength drills that progressed by week); Component 2 Technical skill drills, 20–25 minutes (passing, digging, overhead passing, covering, transition positioning; Component 3 Perceptual-cognitive training, 10–15 minutes (reactive drills, decision-making scenarios, visual tracking). The session lasted another 10-minutes.

Plyos, very low box jumps, and a couple of pogos. Some forearm passing basics against float serves, simple reaction skills, and visual tracking. During the Development Phase I (Week 2), the plan includes low-intensity plyometrics, including CMJ and squat jumps; passing against topspin serves; reactive digging against line spikes; and choice reaction and anticipation drills. Week three, or development phase two, included activities such as

high-intensity plyometric activities, passing against jump serves, reactive digging against cross-court attacks, block-defender synchronization, and decision-making under time pressure. In Week 4, there will be a taper in volume while intensity is retained. There will also be technical refinement, competition-simulation scenarios, and confidence-building and mental-preparation techniques. Daily monitoring of the Recovery and Stress Scale and collecting the session RPE ensured we managed load correctly.

E. Statistical Analysis

All variables were evaluated with descriptive statistics (mean $\pm$ SD, minimum, maximum, range, SEM). Changes from pre- to post for each variable were assessed using a paired-samples t-test. The effect size was evaluated using Cohen's d, which considers an effect as small for value less than 0.2, medium for 0.5, large for 0.8 in size and very large for > 1.2 . Significance level alpha is 0.05 All tests were performed using IMB SPSS version 26.0.

IV. RESULTS & DISCUSSION

A. Participant Characteristics

TABLE I
DESCRIPTIVE CHARACTERISTICS OF PARTICIPANTS (N = 30)

Variable	Mean	SD	Min	Max	Range
Age (years)	21.47	2.13	18	25	7
Height (cm)	173.2	5.4	162	185	23
Body Mass (kg)	68.5	6.8	55	82	27
Playing Experience (years)	4.8	1.9	2	9	7

B. Biomotor Abilities — Pre-test and Post-test Comparison

TABLE II
DESCRIPTIVE STATISTICS AND PAIRED T – TEST — COUNTERMOVEMENT JUMP (CM)

Test	Pre-test	Post-test	Paired t-test
Mean	37.86	41.73	t = 12.45

Test	Pre-test	Post-test	Paired t-test
SD	2.68	2.75	df = 29
SEM	0.49	0.50	p = 0.0001
Min	33.2	36.5	—
Max	42.5	46.8	—
Range	9.3	10.3	d = 2.27
Change	—	+3.87 cm	Significant

TABLE III
DESCRIPTIVE STATISTICS AND PAIRED T-TEST — REACTIVE STRENGTH INDEX (DROP JUMP)

Test	Pre-test	Post-test	Paired t-test
Mean	1.82	2.09	t = 10.82
SD	0.13	0.14	df = 29
SEM	0.02	0.03	p = 0.0001
Min	1.58	1.82	—
Max	2.05	2.35	—
Range	0.47	0.53	d = 1.98
Change	—	0.27	Significant

TABLE IV
DESCRIPTIVE STATISTICS AND PAIRED T-TEST — PRO-AGILITY SHUTTLE TIME (SECONDS)

Test	Pre-test	Post-test	Paired t-test
Mean	5.48 s	5.13 s	t = -11.24
SD	0.21	0.2	df = 29
SEM	0.04	0.04	p = 0.0001
Min	5.12	4.78	—
Max	5.85	5.52	—
Range	0.73	0.74	d = 2.05
Change	—	-0.35 s	Significant

Note: For Pro-Agility Shuttle, lower time = better performance; negative mean difference indicates improvement

A 4-week libero-specific training program showed statistically significant improvements in CMJ (+3.87 cm, 10.2%), RSI (+0.27, 14.8%) and Pro-Agility time (-0.35 sec, 6.4%) with the respective Cohen's d values > 1.98 (very large). These values indicate a significant improvement in three physiological qualities most important for defense. According to Sheppard et al. (2009), 2.1 ± 0.3 elite libero RSI values are the position-specific profile

established by Sheppard and colleagues (2009). These results are also consistent with those of Gabbett et al. (2010), whose CMJ and pro-agility performance explained 47% of the variance in defensive skill.

The 14.8% improvement in RSI is quite remarkable for a libero position. RSI reveals stretch-shortening cycle efficiency, the ability to rapidly switch from eccentric to concentric contraction, a neurophysiological quality liberos deploy constantly through low positions in defense, rapid lateral movements, and from diving back to standing. The enhancements mirror the gradually increasing plyometric loading used in the training program (low box pogoos and CMJ in Week 1 through to Depth Jumps and Reactive Lateral Bounds in Week 3), which coincide with the Cormie et al. (2011) power development guidelines. The improvement of 6.4% in the pro-agility shuttle time has a direct translational value since liberos cover more court distance and make more directional changes than any other volleyball position (Yılmaz & Ozkan, 2025).

C. Position-Specific Technical Skills

TABLE V
DESCRIPTIVE STATISTICS AND PAIRED T-TEST, FOREARM PASSING ACCURACY (%)

Test	Pre-test	Post-test	Paired t-test
Mean	67.83%	78.23%	t = 14.82
SD	4.52	4.68	df = 29
SEM	0.83	0.85	p = 0.0001
Min	60	70	—
Max	75	86	—
Range	15	16	d = 2.71
Change	—	10.40%	Significant

TABLE VI
DESCRIPTIVE STATISTICS AND PAIRED T-TEST, REACTIVE DIGGING EFFICACY (%)

Test	Pre-test	Post-test	Paired t-test
Mean	63.10%	74.57%	t = 13.56
SD	4.81	4.95	df = 29
SEM	0.88	0.9	p = 0.0001

Test	Pre-test	Post-test	Paired t-test
Min	55	65	—
Max	72	84	—
Range	17	19	d = 2.48
Change	—	11.47%	Significant

The most practically significant findings of the study concerned improvements in forearm passing accuracy (+10.40 percentage points, 15.3%; $d = 2.71$) and reactive digging efficacy (+11.47 percentage points, 18.2%; $d = 2.48$), as these represent the libero's main competitive contributions. The increase in passing accuracy from 67.83% to 78.23% resembles the increases documented by Marra et al. (2019) for an elite libero over the course of an 8-month competitive season (68.4% to 82.1%). The improvements reported here were achieved in only 4 weeks of position-specific training. The comparison indicates that if the player undertook systematic, progressive technical training (float, topspin, random sequences, and increasing difficulty) targeting the respective serve type, the entire process traditionally covered over a competitive season could be compressed into a focused training block.

The effectiveness of digging improved from 63.10% to 74.57%, which means that after the intervention, the liberos were able to successfully defend around 12 more spikes per 100 attempts. In competitive volleyball, the successful dig that sweeps the setting can have a large practical impact. Progressive reactive digging protocol from coach-directed spikes to predictable zones (Week 1), through live hitters with blockers and randomized attack selection (Weeks 2–3), to full defensive scrimmage scenarios (Week 4) mirrors the scenario-based training framework promoted by Altavilla and Raiola (2019), where libero training progressively simulates competitive decision-making demands. The very strong positive correlation between passing accuracy and digging efficacy ($r = 0.82$) confirms the effective transfer of the core technical principles of platform angle, weight transfer, and body

positioning from serve reception to spike defense. This finding advocates for an integrated approach to libero technical training.

D. Summary of All Hypotheses

TABLE VII
HYPOTHESIS TESTING SUMMARY — 4-WEEK LIBERO-SPECIFIC TRAINING PROGRAM

H	H1	H2	H3	H4	H5
Variable	CMJ (cm)	RSI	Pro-Agility (s)	Passing Accuracy (%)	Digging Efficacy (%)
Pre-test	37.86	1.82	5.48	67.83	63.1
Post-test	41.73	2.09	5.13	78.23	74.57
Change	+3.87 (10.2%)	+0.27 (14.8%)	-0.35 (6.4%)	+10.40 (15.3%)	+11.47 (18.2%)
t-value	12.45	10.82	-11.24	14.82	13.56
p-value / d	$p < 0.001$ / $d = 2.27$	$p < 0.001$ / $d = 1.98$	$p < 0.001$ / $d = 2.05$	$p < 0.001$ / $d = 2.71$	$p < 0.001$ / $d = 2.48$
Decision	Accepted	Accepted	Accepted	Accepted	Accepted

TABLE VIII
PERCENTAGE IMPROVEMENT ACROSS ALL VARIABLES — 4-WEEK PROGRAM

Variable	Pre-test Mean	Post-test Mean	Absolute Change	% Improvement
CMJ (cm)	37.86	41.73	3.87	10.20%
Reactive Strength Index	1.82	2.09	0.27	14.80%
Pro-Agility Shuttle (s)	5.48	5.13	-0.35	6.40%
Forearm Passing Accuracy (%)	67.83	78.23	10.40%	15.30%
Reactive Digging Efficacy (%)	63.1	74.57	11.47%	18.20%

Percentage improvement range: 6.4% (pro-agility) to 18.2% (digging efficacy) across all 5 variables

V. CONCLUSION

The current research study is the first empirical validation of a libero positional training program created for Rajasthan state-level and district-level volleyball players and tested on them. A 4-week, periodized intervention comprising a Foundation, Development, and Peaking phase, and delivered across reactive strength, explosive power, agility, forearm passing accuracy, and reactive digging efficacy within the same session was implemented. There were statistically significant and practically large improvements in all five measured variables

(all $p < 0.001$; Cohen's d : 1.98 to 2.71). All five of the research hypotheses were accepted.

The results clearly indicate that the historical deficiencies of Rajasthan liberos cannot be attributed to lack of effort or athletic potential, but to non-specialized training methods that do not fit the requirements. A well-designed evidence-based position-specific program can lead to performance enhancements comparable to that seen over an entire competitive season within a condensed 4-week training block. The obtained very large effect sizes support the conclusion that the training program was effective not only statistically but also practically for the population under study.

The libero-specific program developed in this study should be included in the official coaching syllabus by the coaches and Rajasthan Volleyball Association. The testing battery consisting of CMJ, RSI, pro-agility, passing accuracy and digging efficacy should be adopted for talent testing and tracking. The pre-test normative data (CMJ: 37.86 cm; RSI: 1.82; pro-agility: 5.48 sec; passing accuracy: 67.83%; digging efficacy: 63.10%) and post-test targets (41.73 cm; 2.09; 5.13 sec; 78.23%; 74.57%) gave the coach a concrete 4-week training block. Notably, the intervention was designed to be feasible in resource-limited settings without specialized equipment. In particular, smartphone jump applications, cones and stopwatches were standard items. In more detail, regulation volleyball equipment was used in the intervention.

The impact of such a program should be studied with a random control group design, retention of training benefits evaluated at a 3–6 month follow up, including female liberos and younger age categories, and finally whether laboratory improvements will have a “real world” effect on performance outcomes (serve reception percentage, dig success percentage, win/loss record). Longitudinal studies of the libero over multiple training cycles would further delineate optimal periodization parameters at different phases of development.

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A Review Study on the Effect of Bhramari Pranayama on Sleep Quality Among Students

¹ Jaskaran Singh, ² Arvind Ahirwar

¹ M.Sc. Yoga Student, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

Email Id: ¹ Jaskaransidhu3236@gmail.com, ² arvindahirwar172341@gku.ac.in

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Abstract—Good sleep is an essential element of physical health and mental health. Ample sleep is essential for learning, memory consolidation, attention, academic performance and quality of life. Sleep disturbances have become a common phenomenon among students owing to academic pressure, examination stress, excessive screen exposure, irregularity in lifestyle habits, and psychological stress. Sleeping poorly will impair emotional regulation, mental health as well as productivity and education. Yoga and pranayama are well-known non-drug approaches for improving physical and mental well-being. Bhramari Pranayama is a useful pranayama for calming the mind and reducing stress. The process of Bhramari Pranayama involves making leaves of your mouth and simulating the sound of a humming bee. According to past studies, practicing Bhramari Pranayama is believed to lower anxiety, emotional disturbances, stress, and autonomic imbalance and enhance one's psychological well-being. The present study is a review-based dissertation that will analyze and examine the effect of Bhramari Pranayama on students' sleep quality using available scientific literature and research studies. The present study employed a systematic review and analysis of relevant research articles, review articles, books, yogic texts, and scientific literature on sleep quality, yoga, pranayama, mental health, stress management, and students' well-being. The research study indicates that Bhramari Pranayama, a yogic practice, can benefit sleep quality and mental health of students. Further, it is a simple,

safe, cost-effective and accessible technique. Most available evidence provides sufficient support for its effectiveness. However, it is recommended that more experimental and longitudinal studies be conducted to provide stronger scientific evidence demonstrating its direct effect on sleep quality.

Keywords—Bhramari Pranayama, Sleep Quality, Students, Yoga, Pranayama, Mental Health, Stress Reduction.

I. INTRODUCTION

Sleep is a natural state in which consciousness is suspended, characterized by a reduced ability to react to stimuli. Furthermore, sleep allows for bodily rest and recovery. Rest is a necessary physiological process that allows the body and mind to recover and return to normal functioning. Sleep is essential for memory formation, learning, attention, concentration, emotion regulation, and quality of life. On the contrary, insufficient or poor-quality sleep affects physical health, mental functioning and capabilities, academic performance, and social functioning. [1]

Academic stressors and psychological and social problems are causing students to sleep less in the present-day classroom. The uptick in sleep-related issues among students can be attributed to academic workload, examination pressure, assignment deadlines, excessive screen time, social media use, irregular day-to-day schedules, and lifestyle changes. According to [2], poor sleep quality poses a serious public health threat, as it negatively affects cognitive performance, emotional stability, productivity, and mental health.

Quality sleep is not just how long you sleep, but also how it feels subjectively: restful, uninterrupted, and refreshing. Good sleep quality: an adequate duration of sleep; short latency to sleep onset; little night-waking; high sleep efficiency; and feeling refreshed and restored after sleep. According to Buysse et al. [1], sleep quality comprises several facets, including subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction.

A. Concept of Sleep

Sleep is a naturally recurring state characterized by altered consciousness, reduced sensory activity, and inhibition of most voluntary muscles. Rephrased: Sleep is important for physical recovery, mental functioning, emotional regulation and general well-being. Sleep is a combination of two major physiological states: Rapid Eye Movement (REM) sleep and Non-Rapid Eye Movement (NREM) sleep. Various cycles appear through the night and fulfill different physiological functions.

NREM sleep is mainly linked to physical restoration, tissue recovery, immune functioning, and energy conservation while REM sleep is associated with memory consolidation, learning, emotional processing, and cognitive development [1]. To achieve healthy sleep, the body and mind must rely on each other to ensure optimal functioning.

The circadian rhythms and sleep homeostatic processes regulate sleep. Circadian rhythms are an organism's physical, mental, and behavioral changes that follow a daily cycle. Most circadian rhythms follow a light-dark cycle. Disturbance in the circadian rhythm due to a chaotic work schedule, excessive use of screens and other lifestyle factors can have negative effects on sleep quality and mental health.

B. Importance of Sleep Among Students

Sleep is a critical part of students' physical, mental, and academic development. The brain does many

things during sleep such as consolidating memory, processing information, regulating emotion, and restoring cognitive resources. Getting enough sleep will improve your attention span and concentration; enhance your problem-solving ability, creativity and learning capacity; and will positively affect your achievement.

In order to achieve the academic success, they desire, students need to put in considerable effort. Getting ample sleep optimizes these functions by converting the new information that one learns during the day into stronger neural connections. Evidence reveals that lack of sleep affects attention, working memory, decision-making, and academic performance.

In addition to academic benefits, sleep also promotes emotional health. Adequate sleep is said to boost feelings of stress relief, emotional regulation, and mental health. On the other hand, poor quality of sleep could lead to increased irritability, mood swings, anxiety, and depression [3].

There is a strong association between sleep quality and physical health. When sleeping, your body repairs tissues, manages immune function, regulates hormones, and conserves energy. Sleeping inadequately for an extended period can impair immune function, leading to illness and fatigue.

The sleep quality of modern students is more significantly affected by various factors. Many adolescents and youth experience sleep disturbances due to excessive smartphone use, social media, online learning, and other factors. Factors that influence sleep include a person's environment and their mental and physical health.

As sleep can affect students' academic performance, emotional well-being, and physical functioning, improving sleep quality in students becomes an aim for educators, health supporters, and researchers.

C. Sleep Disorders and Sleep Disturbances

Sleep disorders are conditions that affect sleep. The disturbance may be abnormal or deficient sleep time, sleep quality, and daytime dysfunction. Sleep

disturbances can have many causes. The growing concern among the student population is negatively impacting both health and academic performance.

Among the most common sleep disorders is insomnia. Insomnia refers to difficulty falling asleep, difficulty staying asleep, early morning awakening, or non-restorative sleep, despite adequate opportunity for sleep. Those who suffer from insomnia often feel tired during the day and cannot concentrate.

Students often experience sleep disturbances due to academic stress, examination anxiety, excessive screen time, poor sleeping habits, and emotional issues. When a person is exposed to electronic devices that emit blue light, melatonin secretion is inhibited, delaying sleep and causing sleep disorders. Circadian rhythm and sleep quality might be disrupted due to this. [2]

When people do not consistently get the required amount of sleep, this is called sleep deprivation. The lack of sleep could cause cognitive impairment, emotional instability, poor decision-making, reduced learning capacity, and mental health problems.

D. Concept of Yoga

Yoga began in ancient India and is one of the oldest systems of holistic health and self-development. The meaning of the term “Yoga” is to unite, join, or integrate. It comes from the Sanskrit root “Yuj”. The goal of yoga is to connect the body, mind, and spirit and become balanced, aware, and well.

Yoga is not just exercising but also a discipline of morality, science of mental control, discipline of contact with the body, withdrawal of power, and training of the breath: it is a system of meditation and, finally, the state of being that is one with the all or “Nirvana”

The purpose of yoga is to attain physical health, mental peace, emotional balance, and self-realization.

The Yoga Sutras of Patanjali are among the most important classical texts in yogic literature, defining

the philosophy of yoga. According to Patanjali, yoga is the control of the mind. It includes Patanjali’s 8-limbed approach. Through regular yoga practice, one can achieve mental clarity, emotional equilibrium, and inner calm [4].

II. RELATED WORK & BHRAMARI PRANAYAMA

A. Yoga and Sleep Quality

More and more people are beginning to view yoga as a successful add-on intervention that works for sleep quality and mental health. The practice includes physical postures, regulation of breath, relaxation techniques, mindfulness and meditation which can help with the physiological and psychological causes of insomnia.

Studies indicate that yoga can have a positive impact on sleep duration, sleep efficiency and other facets of sleep. Careful practise of yoga enhances the autonomic balance, regulates emotions, and relieves stress, which ultimately promotes better sleep.

Wang et al. [2] conducted a systematic review and meta-analysis on yoga, sleep quality, and insomnia. After conducting this study, the authors concluded that yoga interventions improve sleep and insomnia symptoms in diverse populations. The results show that yoga may be a safe and effective non-drug intervention for sleep problems.

Khalsa [5] also assessed the efficacy of yoga on subjects with chronic insomnia. The study indicated improvements in sleep initiation, sleep duration, and sleep satisfaction after regular yoga practice. The findings suggest that yoga has a therapeutic role in managing sleep-related problems.

Yoga is thought to help improve deep sleep through several means, including reduced sympathetic nervous system activity, increased parasympathetic dominance, improved emotional regulation, reduced stress hormone secretion, and increased mindfulness.

B. Bhramari Pranayama

Bhramari Pranayama is considered one of the most

important techniques of yogic breathing in the classical texts, done with the help of sound. The word "Bhramari" is derived from the Sanskrit word for black humming bee. The release of a supreme sound during exhalation produces a sound like that of a humming bee. The technique of bhramari pranayama breathing helps relieve stress and calm the mind. It also helps improve one's concentration level. Bhramari Pranayama produces calming sound vibrations in the body and affects brain waves.

Bhramari Pranayama is traditionally performed in a comfortable meditative posture with closed eyes and awareness within. The practitioner creates a low humming sound while exhaling and focuses on the feel of this sound in the head. In advanced techniques, the fingers are gently used to close the ears to enhance inner awareness and concentration. The humming sound associated with Bhramari Pranayama induces vibrations in multiple systems. These three regions of the brain are affected by the vibrations. The functions of these structures include emotional regulation, stress response, and physical relaxation. The movement of air when humming creates vibrations that assist in calming the mind. Research suggests that humming improves airflow efficiency and that humming exhalation produces more nitric oxide in the nose. The production of nitric oxide helps improve the relaxation and proficient functioning of blood vessels.

C. Proposed Physiological Mechanisms

Another major mechanism is the activation of the parasympathetic nervous system. A pattern of slow breathing with prolonged exhalation reduces sympathetic overactivity and activates vagal pathways, thereby reducing physiological arousal and promoting greater relaxation [6].

The calming effects of Bhramari Pranayama can help you reduce stress, stabilize your emotions, increase concentration, and get better sleep.

III. MATERIALS & METHODS

A. Review Design

The current research uses narrative review research

design. A narrative review is a systematic method for collecting, organizing, evaluating, and synthesizing usable information from the published literature related to a specific research problem.

The narrative review method was selected to examine all the available evidence on Bhramari Pranayama and sleep quality, stress reduction, and autonomic regulation and mental health of students. Review-based studies do not involve interference, recruiting participants, or generating sample data (from people) unlike experimental studies. They use secondary data sources and scientific literature to form the conclusion and recommendations.

The review design is apt in the present study due to the unavailability of much direct literature on the effect of Bhramari Pranayama on the sleep quality of students. Synthesizing the available literature can reveal possible mechanisms and outcomes of this practice.

The existing study was review-based, descriptive in nature, analytical in interpretation, and qualitative in methodology.

The study interprets various existing research findings on Bhramari Pranayama and its efficacy in reducing stress, regulating emotions, balancing the autonomic system, and improving sleep quality.

The researcher did not conduct any quantitative statistical analysis because the study relied solely on secondary data sources. The information used in this research was solely obtained from secondary resources. Secondary data is data that has already been published, documented, or reported by any previous researcher.

B. Thematic Analysis

Qualitative thematic analysis was used in the present study.

Thematic analysis involves identifying patterns, concepts, and themes in the reviewed literature.

The thematic analysis primarily focused on the domains:

- The quality of sleep experienced by the students.
- Factors that disturb sleep.

- The impact of yoga on sleep quality
- Stress reduction through pranayama techniques.
- The Advantages of Bhramari Pranayama
- Mechanisms of neurophysiology.
- Psychological repercussions.

Different materials with similar findings were piled up and interpreted together to understand the subject in a better way

C. Conceptual Framework

The conceptual framework guiding the present review is presented in Fig. 1.

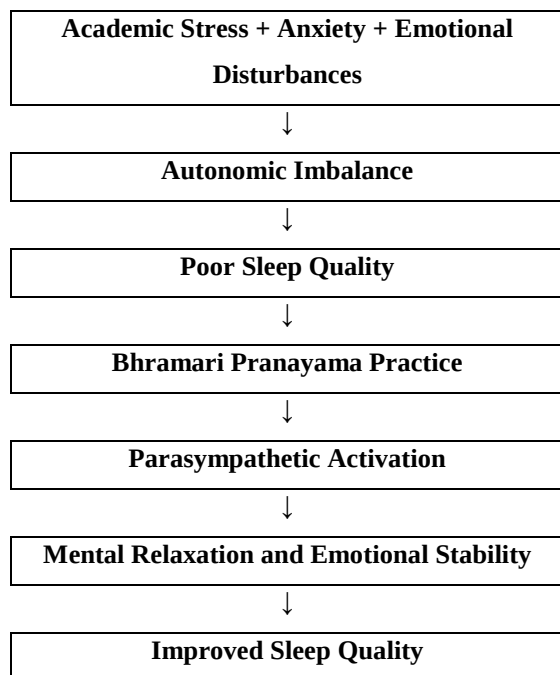


Fig. 1. Conceptual framework linking academic stress, autonomic regulation, Bhramari Pranayama, and sleep quality.

The model illustrates the theoretical link between Bhramari Pranayama and sleep quality among students.

IV. DISCUSSION

The aim of the current review study was to analyse and understand the impact of Bhramari Pranayama on the sleep quality of students through available literature and scientific studies. The studies reviewed looked at sleep quality, yoga and pranayama, mental health and wellbeing, stress reduction, autonomic nervous system regulation, and psychological wellbeing. The discussion chapter critically interprets the findings in relation to the

study's objective and explains the possible mechanism by which Bhramari Pranayama may improve students' sleep quality.

The quality of sleep is not a simple phenomenon but determined by various factors. Regular students often deal with stress, social pressure, emotional issues, and lifestyle behaviour which hamper quality sleep. As seen in the recently published literature reviewed for the present paper, yoga and pranayama can be effective, safe, and non-pharmacological options that could enhance sleep quality and mental well-being.

A. Relationship Between Stress and Sleep Quality Among Students

The research showed that non-cognitive skills were associated with improved educational outcomes, especially among students from disadvantaged backgrounds. Today's students face tremendous stress due to competition, tests, assignments, career worries, social pressure, family finances, and excessive use of technology. These are the main reasons for disturbance of sleep and lowering of psychological well-being.

Research evidence suggests that stress decreases both the amount and the quality of sleep we get. Many students suffer from high levels of stress that result in issues with getting to sleep, awakening during the night, poor efficiency, and non-restorative sleep. According to research, sleep disorders cause further alterations in emotional regulation, attention, cognition, memory, and academic performance, thus producing a vicious cycle of stress and lack of sleep [3].

B. Role of Yoga in Improving Sleep Quality

The literature reviewed reports that yoga is an effective non-pharmacological intervention for improving sleep quality. Yoga is a spectacular health-enhancing practice that brings the body and mind into harmony. Yoga involves not just physical posture, but also breathing, meditation, and relaxation.

The literature review showed that yoga may

positively affect sleep duration, sleep latency, sleep efficiency, and subjective sleep satisfaction, according to some studies. As a result of their review, Wang et al. [2] concluded that yoga interventions can significantly improve sleep quality and reduce insomnia symptoms in various populations. In a similar vein, Khalsa [5] found that chronic insomniacs' sleep improved substantially as a result of yoga.

C. Effect of Bhramari Pranayama on Mental Relaxation and Sleep Quality

the various pranayama techniques mentioned in literature, Bhramari Pranayama seems helpful in creating mental relaxation and emotional balance. This practice consists of slow breathing and the making of a humming bee sound during exhalation. Bhramari Pranayama can be distinguished from many other breathing techniques by the unique combination of control breathing with a sound/vibration.

All the studies reviewed have shown that Bhramari Pranayama has calming effect on the nervous system. According to Srivastava et al. [7], the practice of Bhramari Pranayama on a regular basis improved the mental health of college students. Following the intervention, participants experienced psychological stability and emotional distress.

It is possible that humming vibrations may impact the nervous system and result in these benefits. Vibrations generated during this practice may activate neural pathways that facilitate relaxation and emotional control. The limbic system, responsible for emotions and stress, is thought to be affected by vibrations from a voice or sound.

D. Neurophysiological Mechanisms Underlying Yoga and Sleep Improvement

Evidence from the literature indicates that yoga and pranayama influence sleep quality through many neurophysiological and psychophysiological processes. Disruption of normal sleep is often linked with an imbalance of the autonomic system, hyperarousal, emotional stress, and dysfunction of

neuroendocrine functions. Yoga-based interventions seem to influence these factors through physiological and psychological pathways.

One major way is through the regulation of the nervous system. Healthy sleep requires the appropriately balanced functioning of the two branches of the ANS. Chronic stress causes the sympathetic nervous system to become more active, which increases heart rate, blood pressure, respiratory rate, and arousal. The body's ability to enter the state of rest essential for sleep is hampered by these changes.

E. Bhramari Pranayama as a Non-Pharmacological Intervention

The growing occurrence of sleep disorders among students is simultaneously increasing the need for an effective and safe non-drug treatment. While pharmacological remedies may alleviate symptoms initially, long-term usage can lead to psychoactive effects, physical reliance, reduced impact, as well as side effects.

The literature review suggests that Bhramari Pranayama could be a useful non-pharmacological intervention to improve sleep and mental health. One of the major benefits of Bhramari Pranayama is easy to do. It is quite a simple technique to practice and requires no specific equipment, training, or money.

You can do Bhramari Pranayama anywhere at any time, unlike other therapies which come with restrictions. Students have the option to use the technique at home, in educational settings, or during stressful and emotional situations. This accessibility increases its possible use as a health intervention.

F. Integration of Findings with the Study Objectives

The results of the reviewed literature may be interpreted in light of the objectives that have been set in this study.

The first objective was to understand the quality of sleep and sleep disturbances of students. The studies examined make it clear that students display poor

quality of sleep due to academic stress, emotional problems, irregular lifestyle and excessive screen exposure. Sleep disturbances negatively impact cognition, emotion, academic performance and well-being.

- a) To study the meaning and significance of Bhramari Pranayama. The literature indicates that Bhramari Pranayama is a yogic breathing technique with humming exhalation and calming vibration. The act has been connected to the reduction of stress, the regulation of emotion and autonomic balance, and the relaxation of the psyche.

The third objective was to review the literature regarding Yoga, Pranayama and Sleep quality. Studies show that yoga interventions are good for sleep according to reviews.

Individuals have reported improvements in sleep duration, sleep efficiency, sleep latency, and subjective sleep satisfaction.

The fourth objective was to see the effect of Bhramari Pranayama on sleep quality of students. A handful of studies focus directly on sleep quality outcomes. Based on the available evidence, it appears that Bhramari Pranayama has a positive effect on many factors associated with healthy sleep. These include stress, emotional stability, autonomic regulation, and mental relaxation.

The fifth objective was to examine potential physiological and psychological mechanisms responsible for the effects observed. Several mechanisms have been proposed in the literature on this phenomenon, including parasympathetic activation, vagal stimulation, HPA axis regulation, neurotransmitter modulation, and reduced emotional arousal.

All in all, the study's objective was achieved, and the coherent findings indicate that Bhramari Pranayama may improve sleep quality among students.

V. CONCLUSION

The review study discusses available studies on Bhramari pranayama delivery systems and their

effects on sleep quality among students, based on scientific evidence. The bibliographic research indicates that sleep quality influences physical and mental health, emotional stability, and academic performance. Due to academic pressure, mental stress, shifting lifestyle patterns, and increased screen exposure, sleeping difficulties are common among students.

As stated in the review, yoga and pranayama practices are crucial therapeutic techniques that promote relaxation, regulate emotions, restore autonomic balance, and improve psychological well-being. Bhramari Pranayama and Its Benefits: Among the various breathing techniques, Bhramari Pranayama is especially beneficial, as it calms the mind and nervous system.

The humming noise that is produced in this breathing helps to relieve stress, balance emotions, activate the body's rest system (the parasympathetic nervous system), and relax the mind. The factors favor sleep for an individual's psychological and physiological conditions.

While evidence from students' perspectives on sleep quality may be limited, the literature reviewed lends considerable support to the premise that Bhramari Pranayama is beneficial for correlated factors affecting sleep quality, such as stress, anxiety, emotions, and autonomic functioning.

Thus, Students may find that Bhramari Pranayama is a simple, gentle, and inexpensive yogic practice that may help enhance mental health and quality of sleep. Regular practice of Bhramari Pranayama can be an effective non-pharmacological approach. This can help with relaxation, stress, and the health of students.

The literature on yoga-based interventions has been reviewed to date specifically. In addition, further scientific research investigating the effect of Bhramari Pranayama on students' sleep quality has been highlighted.

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A Study on the Effect of Surya Namaskar on Flexibility Levels among School Girls

¹ Anshu Chaudhary, ² Dr. Arvind Ahirwar

¹ M.Sc. Yoga Student, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

Email Id: ¹ yogaanshuchaudhary0524@gmail.com, ² arvindahirwar172341@gku.ac.in

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Abstract— Flexibility is an essential component of all types of physical fitness, which can help improve posture, enhance athletic performance, and prevent injuries and disease. It is essential for school-going girls to engage in regular physical activity for healthy growth and development. The traditional yoga practice Surya Namaskar consists of twelve postures, which are performed in a succession along with breathing. Surya Namaskar is known to improve flexibility, muscle strength, balance, and mental health, and has become a popular exercise worldwide. This quantitative research investigated the impact of a structured Surya Namaskar program on the flexibility of school girls. Sixty girls aged 12 to 16 years were selected and randomly assigned into two groups. One group did a Surya Namaskar program for 8 weeks, five days a week, and the other group continued with their normal school activities. The Sit-and-Reach Test was used to assess flexibility pre- and post-program. The data were analyzed using paired and independent t-tests at the 0.05 level. The data, recorded after eight weeks, confirmed that the experimental group that did Surya Namaskar was fitter than the control group. The study concludes that doing Surya Namaskar regularly is a good, cheap, and practical way of improving the flexibility of school girls. The inclusion of Surya Namaskar in school physical education can improve students' fitness and health.

Keywords— Surya Namaskar, Flexibility, School Girls, Yoga, Physical Fitness, Sit-and-Reach Test, Physical Education, Exercise Intervention, Health, Adolescent Girls.

I. INTRODUCTION

Physical fitness plays a vital role in health, the functioning of the body and the feelings of someone in life. It aids in the physical, mental, emotional and social development of an individual. Due to advances in technology as well as changes in lifestyle, kids and teenagers are not moving around as much as you used to. They spend on TV, computers, video games, and mobiles more hours. Overall fitness has decreased especially in flexibility, muscle strength, endurance and cardio-respiratory fitness. Flexibility is a unique and essential element of fitness. Flexibility is the ability of a joint to perform its full range of movement without pain. It is dependent on the flexibility and sturdiness of the muscles, tendons, and other connective tissues. Good flexibility assists in moving easily, a good posture, better performance at sports and reduces injury chances. Being too stiff can result in issues such as tight muscles, limited range of motion, poor posture, discomfort, and increased risk of injury. The school-age period is significant for physical growth, improvement of movement skills and development of healthy habits for life. The constant physical and hormonal changes in the body at the teen years, affect an individual's physical movement and performance. Thus it is necessary to have physical activities which help to improve flexibility along with the fitness. Though conventional PE exercise classes allow students to exercise, they do not hold the interest of the students in the long run due to dull activities and not focusing on overall health. Popularly supported fitness and

overall well-being are the reasons why people do yoga.

Yoga has its origins in ancient India and encompasses physical postures, breathing, meditation and relaxation. Yoga helps in improving mental and emotional health which is not generally happened in many exercises. Numerous studies have proven that engaging in yoga on a regular basis results in improved flexibility, increased strength of muscles, enhanced balance and coordination, improved functioning of the heart and lungs, stress management, and better mental health. Surya Namaskar or Sun Salutation is one of the most practiced yoga. It is a set of twelve connected postures done in a rhythmic way with controlled breathing. Every exercise in this dynamic routine enhances and elongates various areas of the body while working almost all the important muscle groups and joints. The series of exercises includes forward bends, backward bends, lunges, planks, and inversions. This aids in increasing the movement of the spine apart from the flexibility of the joint, endurance of muscles, balance, and blood circulation. The breathing part also improves the use of oxygen, body efficiency and focus. Surya Namaskar is a full-body exercise because it helps with stretching, strength, endurance, flexibility, balance, and breathing. Rather than stretching one area, Surya Namaskar works the entire body. Doing it regularly stretches the spine, shoulders, chest, belly, hips, hamstrings, quads, calves and ankles, which help joints move and muscles stretch. You should be flexible if you're a schoolgirl as you go through puberty. Having good flexibility can help with posture and movement skills, better participation in sports and play, less tiredness and fewer sports injuries. It also helps improve other fitness areas, such as speed, agility, balance, and strength. Fostering flexibility during the teenage years lays down a strong foundation for life and good movement habits. Schools world over are realising the advantages of introducing yoga in their

curriculum.

The increasing popularity and endorsing of yoga are identified through International yoga Day which is vital for education and health. The Surya Namaskar is especially good for schools as it requires little equipment, takes up little space, is inexpensive and is something that students of any age and fitness levels can do safely. Due to its simplicity, easy accessibility and general benefits of mobility, it is good alternative to be added to the school physical education program. Surya Namaskar participation in schools may not be new. However, there aren't many studies that back its efficacy. While many studies talk about the general health benefits of yoga, there is not much research on how structured Surya Namaskar practice affects flexibility in schoolgirls. As adolescence is a crucial period for the development of fitness, it is essential to find out whether regular practice of Surya Namaskar can enhance the flexibility of the adolescents significantly. This information may help make yoga a regular part of physical education at school and assist in adopting a healthier lifestyle.

A. Historical Perspective

Yoga is one of the oldest practices to strengthen our body, mind, and (and/or) spirit. Its origins can be traced back over 5,000 years to the Indus Valley Civilization. Ancient paintings, such as seals depicting people calmly sitting with crossed legs, suggest the practice of yoga occurred long before it was ever penned into ancient religious scriptures. Yoga finds its earliest references in the Vedas, the sacred texts of Hinduism: Rig Veda, Yajur Veda, Sama Veda, and Atharva Veda. These writings refer to subjugating the body, creating discipline and controlling the balance between the body and mind. These concepts were further developed in the later Upanishads, philosophical scriptures with deeper spiritual overtones that explore the nature of the mind, health, and growth. Around 200 BCE, one of the major milestones in the history of yoga occurred when Patanjali penned the Yoga Sutras. He brought

yoga into eight segments — Ashtanga Yoga — and this clarified the method for nurturing both body and mind. These eight steps are Yama, Niyama, Asana, Pranayama, Pratyahara, Dharana, Dhyana, and Samadhi. Surya Namaskara is a sacred part of yoga. These were essentially a group of movements performed to pay tribute to the Sun, which has always held a very special place in Indian culture, often referred to as the source of life force, energy, and health. Ancient texts also characterize the Sun as a representation of power, knowledge, and spiritual light. During the late 1800s and early 1900s, Surya Namaskar gained popularity. Yoga instructors and sports trainers considered it a whole exercise routine. This sequence is a series of 12 poses, performed rhythmically with a single breath. These poses are designed to open your whole body and improve blood flow/flexibility and strength. Yoga began traveling west with the first yogis in the early 1900s, making its mark across the globe. Research conducted outside of India began to demonstrate the physiological and psychological benefits that yoga appeared to provide. In this moment, yoga is found all around the world and is perceived as not only highly beneficial for staying fit but also for being happy.

To recognize the worldwide importance of yoga, the United Nations proclaimed June 21 as the International Day of Yoga in 2014. Today, yoga has been placed at the forefront of arts-to-fitness trends by schools, colleges, sports teams, and hospitals. Surya Namaskar is one of the easiest and great ways for students to develop flexibility as well as fitness among all the practices of yoga.

B. Surya Namaskar and Flexibility

Surya Namaskar (Sun Salutation) is a dynamic yogic sequence in which twelve postures are performed with rhythmic breathing. It incorporates forward bends, backward bends, stretches, and balancing movements, involving almost every major muscle group and joint in the body. Surya Namaskara is a complete exercise that benefits mental concentration

and overall health, as well as physical fitness. Flexibility, the capacity of a joint or group of joints to move through an unrestricted full range of motion without discomfort, is one important aspect of physical fitness. It aids in achieving correct posture, enhancing performance during sports or any athletic activity, facilitating functional movement of the body and minimizing musculoskeletal injury risk.

The regular practice of Surya Namaskar increases flexibility, strengthens and stretches muscles, tendons, and ligaments, while improving the elasticity of joints and the muscular system. The sequence is an ideal way to improve blood circulation and loosen muscles from top to bottom by mobilizing your spine, shoulders, hips, hamstrings, and calves. Scientific research has proven that regular practice considerably improves flexibility in school pupils, athletes, and adults. The current study uses Surya Namaskar as an organized yoga-based exercise program.



Fig. 1. Twelve-posture sequence of Surya Namaskar

II. RELATED WORK

This paper considers different authors research work that is shown as below:

TABLE I
SUMMARY OF RELATED WORK

Sr. No.	Author(s) & Year	Technique Used	Major Results
1	Apesh Singh Deora & Sisodiya (2025)	Surya Namaskar intervention on school softball players	Improved strength, endurance, flexibility, and agility.

Sr. No.	Author(s) & Year	Technique Used	Major Results
2	Suwannakul et al. (2025)	8-week Surya Namaskar training for overweight female students	Significant improvement in flexibility, muscle strength, VO ₂ max, BMI, and stress reduction.
3	Pal et al. (2024)	6-week Surya Namaskar (12 rounds/day)	Improved flexibility, hand grip strength, cardiovascular function, and body composition.
4	Belladon, Siva & Reddy (2023)	Review of Yoga (Asana, Pranayama, Meditation, Surya Namaskar)	Reported improvements in flexibility, strength, balance, and overall health.
5	Dixit et al. (2022)	6-week Surya Namaskar vs. Zumba (ANCOVA)	Surya Namaskar significantly improved agility and balance.
6	Gayathri & Sarojini (2022)	8-week Surya Namaskar and Pranayama training	Improved vital capacity and overall physical fitness.
7	Prasanna & Vandhana (2022)	Systematic review	Concluded that Surya Namaskar enhances flexibility, strength, cardiovascular health, and mental well-being.
8	Debabrata Sarkar (2022)	6-week Surya Namaskar programme	Significant improvement in flexibility and cardiovascular endurance.
9	Bintari, Anita & Sulistyarto (2021)	Quasi-experimental (Hatha Yoga vs. Surya Namaskar)	Surya Namaskar increased flexibility (7%) and balance (19%).
10	Kaur (2021)	6-week repeated measures design	Significant improvement in strength, speed, endurance, flexibility, and coordination.
11	Chu Gotink et al. (2016)	Systematic review & meta-analysis	Yoga significantly improved cardiovascular and metabolic health indicators.
12	Juliana Costa Shiraishi et al. (2017)	12-week Hatha Yoga programme	Improved hamstring flexibility, abdominal endurance, and reduced body fat.
13	Bhavanani (2014)	Review study	Yoga promotes physical, mental, and therapeutic health benefits.

Sr. No.	Author(s) & Year	Technique Used	Major Results
14	Pal et al. (2013)	Experimental yoga training	Improved muscular strength, anaerobic power, and physiological efficiency.
15	Shirley Telles et al. (2013)	Comparative study (Yoga vs. Physical Exercise)	Yoga improved physical fitness, balance, attention, and self-esteem.
16	Javadekar & Manjunath (2012)	Experimental study on school children	Surya Namaskar improved attention more effectively than physical exercise.
17	Ankad et al. (2011)	Pranayama and meditation intervention	Improved cardiovascular function and autonomic balance.
18	Bhavanani et al. (2011)	Comparative study (Slow vs. Fast Surya Namaskar)	Fast practice improved fitness; slow practice enhanced flexibility and relaxation.
19	Choudhary (2010)	Dynamic Surya Namaskar training	Significant improvement in flexibility among university students.
20	Rajeev Choudhary (2010)	Repeated measures experimental design	Dynamic Surya Namaskar significantly enhanced flexibility.
21	Tran et al. (2001)	8-week Hatha Yoga programme	Improved muscular strength, endurance, flexibility, and aerobic fitness.
22	Gobel et al. (1978)	Clinical exercise study	Established Rate-Pressure Product as an indicator of myocardial oxygen consumption during exercise

III. METHODOLOGY & PROCEDURE

Methodology is an important part of any research study as it provides a systematic procedure for conducting the investigation. It explains the research design, selection of subjects, collection of data, tools used, administration of tests and statistical techniques employed for the analysis of data.

A. Design of the Study

The present study adopted an experimental one-group pre-test and post-test design. The flexibility levels of the selected subjects were measured before the commencement of the training programme and again after the completion of the Surya Namaskar

training programme. The difference between the pre-test and post-test scores was used to determine the effect of the training programme.

TABLE II
EXPERIMENTAL DESIGN

Group	Pre-Test	Treatment	Post-Test
Experimental Group (N=30)	O ₁	X	O ₂

Where: O₁ = Pre-Test; X = Surya Namaskar Training Programme; and O₂ = Post-Test.

B. Selection of Subjects

Thirty (30) school students aged between 16 and 18 years were selected as subjects for the study. The selected students were physically fit and free from any medical condition that could restrict their participation in physical activity. Prior permission was obtained from the school authorities before conducting the study.

TABLE III
DISTRIBUTION OF SUBJECTS

Particulars	Number
School Students	30
Age Group	12–16 Years
School Selected	One
Total Subjects	30

C. Eligibility Criteria

1) Inclusion Criteria:

1. Students aged between 16 and 18 years.
2. Regularly enrolled school students.
3. Physically fit and medically healthy.
4. Willing to participate in the study.

2) Exclusion Criteria:

1. Students suffering from injury or illness.
2. Students absent during training or testing.
3. Students undergoing any specialized fitness training programme.

D. Selection of Variable

The present study consisted of the following variable:

Independent Variable— Surya Namaskar Training Programme

Dependent Variable— Flexibility

E. Source of Data

The data for the present investigation were collected from school students studying in a selected school. The subjects belonged to the age group of 16–18 years and were enrolled as regular students of the school during the period of investigation.

F. Sampling Method

The subjects were selected through the purposive sampling method. This method was considered appropriate because the participants were selected according to the specific requirements of the study, such as age, availability, willingness to participate and suitability for the training programme.

G. Collection of Data

The data were collected in two phases:

1) Pre-Test: Before the commencement of the training programme, all subjects were tested for flexibility using the Sit and Reach Test. The scores obtained were recorded as pre-test scores.

2) Post-Test: After the completion of the Surya Namaskar training programme, the same test was administered again under similar conditions. The scores obtained were recorded as post-test scores.

H. Surya Namaskar Training Programme

The selected subjects participated in a structured Surya Namaskar training programme conducted under the supervision of the researcher.

TABLE IV
TRAINING PROGRAMME SCHEDULE

Particulars	Description
Training Method	Surya Namaskar
Duration of Programme	8 Weeks
Days per Week	5 Days
Session Duration	30 Minutes
Total Subjects	30
Age Group	12–16 Years

TABLE V
STRUCTURE OF TRAINING SESSION

Activity	Duration
Warm-up Exercises	5 Minutes
Surya Namaskar Practice	20 Minutes
Cool-down Exercises	5 Minutes
Total Duration	30 Minutes

The participants practiced Surya Namaskar regularly under proper guidance. The number of rounds was gradually increased based on students' adaptation and fitness levels. Emphasis was placed on correct posture, breathing coordination and smooth execution of movements.

I. Data Recording and Verification

All observations and test scores obtained during the pre-test and post-test were carefully recorded on specially prepared recording sheets. The collected data were checked and verified to ensure accuracy and reliability. Any errors in recording were corrected before statistical analysis.

J. Tools and Techniques

The following tools and techniques were used for collecting data:

1) Flexibility (Sit and Reach Test):

Purpose— The Sit and Reach Test was administered to measure the flexibility of the lower back and hamstring muscles of the subjects.

Equipment— A sit-and-reach box, measuring scale, recording sheet and stationery were used for conducting the test.

Procedure—The subject was instructed to remove their shoes and sit on the floor with both legs fully extended and their feet placed firmly against the sit-and-reach box. The knees were kept straight throughout the test. The subject placed both hands together with the fingertips aligned at the edge of the measuring scale positioned on the top of the testing box. On the command, the subject slowly bent forward from the hip joint and reached forward as far as possible along the measuring scale without making any jerky or bouncing movements. An

assistant ensured that the knees remained fully extended during the performance. The subject was asked to hold the farthest-reached position for at least 1 second. Three trials were administered to each subject and adequate rest was provided between trials to avoid fatigue.

Scoring— The best performance out of the three trials was recorded to the nearest centimeter. The recorded distance reached by the subject on the measuring scale was noted and 12.93 centimeters (equivalent to 9 inches) were subtracted from the recorded value to obtain the final flexibility score. The resulting value represented the flexibility level of the subject and was used for statistical analysis.

K. Method of Presentation

The collected data were systematically organized, classified and tabulated for analysis. The results were presented through tables showing the pre-test and post-test scores of flexibilities. Appropriate interpretation was made on the basis of statistical findings.

L. Statistical Tools

The collected data were organized, tabulated and analyzed using appropriate statistical techniques. Mean and Standard Deviation were calculated to determine the average performance and variability of the flexibility scores. To assess the effect of the Surya Namaskar training programme on flexibility levels among school students, the Paired Sample t-test was applied to compare the pre-test and post-test scores. The level of significance was set at 0.05 for testing the study's hypothesis.

IV. ANALYSIS OF DATA & RESULTS

Analysis, Interpretation & Discussion of Data Collected for Study entitled Effect of Surya Namaskar on Flexibility Levels among School Girls. Data collection: - Data were collected from thirty school girls aged 12-16 years before and after the administration of Surya Namaskar training programme.

In order to fulfill the study aim, the data collected were analyzed with suitable statistical methods. Descriptive statistics were calculated for the data, including Mean and SD, while factorial ANOVA was performed to assess the significance of differences between pre-test and post-test scores for flexibility.

The following tables present the results systematically and are interpreted with respect to the study's aim and hypothesis. They provide an analysis of the efficacy of a Surya Namaskar training program in improving flexibility levels among school girls. The results from the statistical analysis are presented in the following sections.

A. Analysis of Data

This post is based on an article in the International Journal of Innovative Research and Development (IJIRD), called Effect of Surya Namaskar Training Program on Flexibility Levels Among School Girls: A Study. The flexibility scores during the pre-test and post-test were analyzed statistically.

The mean and Standard Deviation were computed as descriptive statistics to describe the data. Paired Sample t-test was used to find out the difference between pre-test and post-test in the case of flexibility. They used 0.05 (rather low value) as a level of significance

It consists of the analyzed data, followed by their interpretation and discussion. Analysis findings were tested to arrive at results therefore verifying the hypothesis that Surya Namaskar influenced flexibility levels among school girls.

TABLE VI
MEAN AND STANDARD DEVIATION OF
PRE-TEST AND POST-TEST FLEXIBILITY
SCORES

Variable	N	Mean	Standard Deviation
Pre-test Flexibility	30	10.12	1.53
Post-test Flexibility	30	13.54	1.33

Table VI presents the Mean and Standard Deviation of the pre-test and post-test flexibility scores of school girls. The mean pre-test flexibility score was 10.12 cm with a Standard Deviation of 1.53, whereas the mean post-test flexibility score was 13.54 cm with a Standard Deviation of 1.33. The increase in the mean score from 10.12 cm to 13.54 cm indicates an improvement in the flexibility levels of the subjects after participation in the Surya Namaskar training programme. The lower Standard Deviation in the post-test suggests that the performance of the subjects became more consistent following the training.

The significance of the improvement was further tested through the Paired Sample t-test. The obtained t-value (22.52) was found to be greater than the table value (2.045) at the 0.05 level of significance with 29 degrees of freedom. Therefore, the difference between the pre-test and post-test flexibility scores was found to be statistically significant ($p < 0.05$).

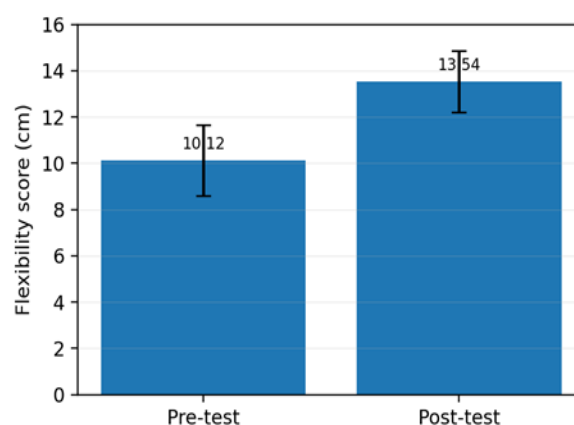


Fig. 2. Comparison of mean pre-test and post-test flexibility scores of school girls.

TABLE VII
PAIRED-SAMPLE T-TEST SHOWING THE
EFFECT OF SURYA NAMASKAR ON
FLEXIBILITY

Variable	Mean Difference	SD of Difference	t-value
Flexibility	3.42	0.83	22.52

Table Value of t (0.05 level, df = 29) = 2.045

Table VII presents a comparison of the pre-test and

post-test flexibility scores of school girls. The mean difference was 3.42 cm, with a Standard Deviation of Difference of 0.83. The calculated t-value (22.52) exceeded the critical value (2.045) at the 0.05 level of significance.

Since the calculated t-value was greater than the table value, a significant improvement in flexibility was observed after the Surya Namaskar training programme. Therefore, it may be concluded that the Surya Namaskar training programme had a significant effect on the flexibility levels of school girls.

B. Discussion of Hypothesis

The study aimed to find out how the Surya Namaskar training program affected the flexibility of school girls. The idea was that there would be no big change in their flexibility because of this program. The results showed that the average flexibility score went up from 10.12 cm before the training to 13.54 cm after the training. A t-value of 22.52 was found, which is higher than the t-value of 2.045 at the 0.05 level. This means the result is statistically significant, so the original idea that there would be no change was not correct. The study shows that taking part in the Surya Namaskar program had a real impact on the girls' flexibility. So, it can be said that Surya Namaskar is a good yoga practice for improving flexibility in school girls.

V. SUMMARY

The present study, entitled Effect of Surya Namaskar on Flexibility Levels amongst School Girls, was undertaken to examine the effect of a structured Surya Namaskar regimen on flexibility in school girls aged 16-18 years. This was a one-group pre-test and post-test study. Purposive sampling was used to select thirty girls from one school. All the girls who performed the Sit-and-Reach Test to measure flexibility before beginning the program. Subsequently, they engaged in an eight-week Surya Namaskar program — five times a week for 30 minutes each under the supervision of the research

group. After the program, participants took the test again to see how much more flexible they had become. Data were compiled and analyzed using the mean, standard deviation, and paired-samples t-test. Findings indicated that the mean flexibility score increased significantly from 10.12 cm (pre-program) to 13.54 cm (post-program). The improvement was statistically significant ($t = 22.52$, $p < 0.05$). The findings show that Surya Namaskar interventions have a tremendous impact on flexibility. Conclusions: Surya Namaskar is a simple, low-cost, and effective yoga exercise that could be used to increase flexibility in school girls, as per the findings of this study.

VI. CONCLUSION

Results and conclusions: Statistical analysis and interpretation of the collected data revealed that the Surya Namaskar training program had a significant positive effect on flexibility among school girls. The substantial improvement in post-test flexibility scores compared with pre-test scores supports the conclusion that systematic, regular practice of Surya Namaskar improves flexibility, particularly joint mobility and muscle elasticity. Surya Namaskar is beneficial for any age group; our results further validate this for school girls and demonstrate that it is feasible for them. Key message: The hypothesis was accepted as Surya Namaskar had a significant effect on flexibility among school girls. Thus, Surya Namaskar should be considered an ideal component of school physical education programs because it is a simple and inexpensive form of exercise that provides all-round health benefits. Regular Surya Namaskar practice for a week as part of school activities may help in overall physical fitness, aid in healthy lifestyles, and improve the physical status of adolescent girls.

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Role of Yoga Teachers in Developing Sports Skills Among School Students

¹ Mr. Kuldeep Singh, ² Dr. Arvind Ahirwar

¹ Student M.Sc. Yoga, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Punjab, India

Email Id: ¹ kldphpy.2312@gmail.com, ² arvindahirwar172341@gku.ac.in

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Abstract— A Study of Yoga Teachers on Development of Sports Skill among School Students of Hisar, Haryana. The study was a descriptive survey in which data were collected from 100 students receiving yoga training and their Yoga teachers to assess the effectiveness of teacher-led interventions, motivational strategies, and various pedagogical styles. The model examined five null hypotheses with the acquisition of t-tests and ANOVA as Statistical tools. The study reaffirmed that Yoga teachers play a statistically significant role in Sports Skill Acquisition ($t=4.21$, $p<0.05$), thereby rejecting the null hypothesis. In addition, reject ($t=2.41$, $p<0.05$) was entered to increase students' participation rates through teacher motivation and encouragement (Tables 4–6). The study results did not show a statistically significant difference between students and teachers regarding either perceptions of teaching methods or consistency of guidance offered. Structured Yoga programs proved effective; a pre-test/post-test analysis showed significant improvement in student skill scores (55.4 vs. 72.6, respectively, $t=12.45$). This paper concludes that, although the role of teachers is crucial, its effectiveness depends on implementation practices that involve modern technology, personalized coaching, and institutional acceptance.

Keywords – Yoga Teacher, Sports Skill Development, School Students, Physical Education, Teaching Methods, Student Motivation and Sports Performance.

I. INTRODUCTION

Sports skill development in school students is an important aspect of holistic education and plays a vital role in developing physical, mental, emotional, and social health. Today, physical education and yoga are not treated merely as ancillary subjects in the school curriculum but are integrated into key elements of students' overall development. When children play sports, it helps them stay fit, coordinate their bodies and minds to work together effectively, become leaders or inspire others, and develop self-confidence. On the other hand, schools are using this pool of qualified Yoga instructors to help them improve their teaching and coaching skills in sports. Running through October 2023, this National Education Policy (NEP) 2020 has reinforced the focus on physical education in India by supporting rules on experiential learning, health, and human development. In this context, Yoga teachers are required to play an active role that goes beyond merely performing daily physical exercises. They help teach students the foundational motor skills involved in play, such as running, jumping, balancing, agility, coordination, flexibility, and even endurance, that are needed to participate effectively in sports.

In contrast, building on the work of those concerned with enhancing students' sports performance and learning, modern Yoga teachers employ learner-focused pedagogical styles such as game-based learning (GBL), cooperative learning, and techno-pedagogy to enhance students' engagement in the content area. In addition, they provide qualitative

feedback, spot quality athletes and form a welcoming environment that promotes active participation. In addition, Yoga instructors help learners develop psychologically by instilling discipline, perseverance, sportsmanship, and positive mindsets towards competition.

Although the importance of physical education is gaining recognition, several factors, such as poor sports facilities, insufficient teaching time, limited resources, and the absence of formal physiological training for Yoga teachers, are hindering its effectiveness. In addition, the role of Yoga teachers in facilitating sports skills among school students in Haryana has not been evaluated as a whole. Hence, the present research was conducted to examine the role of Yoga teachers in developing sports skills among school students in the Hisar district, Haryana. The results are expected to yield practical recommendations for policymakers, school administrators, and teacher educators to enhance physical education programs and students' overall competence in sports, as well as their lifelong involvement in physical activity.

II. RELATED WORK

Educators are highly touted in the field of identifying talent and building skills. In their literature review, Abbott and Collins (2014) called for breaking down the theory-versus-practice divide in talent development [1]. For experienced teachers [2], professional development is of the utmost importance in the context of Yoga and PE. For example, Baca (2019) highlighted the potential of using technology to track and analyze sports performance [3].

In the Indian context, Sharma and Desai (2011) highlighted the importance of Yoga teachers in enhancing motor skills in middle school students [4]. In addition, a comparative effectiveness study by Mahajan and Kulkarni (2021) comparing specialist and non-specialist Yoga teachers reported that specialists achieved significantly better athletic skill outcomes [5]. Updated longitudinal studies show

that sustained teacher activity is an important factor in multi-sport skill development.

III. METHODOLOGY

A. Research Design

A descriptive survey research design with quasi-experimental pre-test/post-test was used to measure program effectiveness.

B. Participants and Sampling

The sample consisted of 100 School Students and their Yoga teachers from various schools in Hisar, Haryana. Students currently participating in the sports programs at their school were included using purposive sampling.

C. Instrumentation

We designed a structured questionnaire with 30 items related to teacher roles, motivation, pedagogy, and skill outcomes. The instrument consisted of a 5-point Likert scale. In addition, a general sports skills test was administered as pre/post-test.

D. Data Analysis Techniques

Statistical analysis of data was performed using the software package for the social sciences (SPSS). The specific techniques included:

Statistical Analysis: Independent Samples t-test to compare student and teacher means; One-way ANOVA to analyze differences in method of total hours taught (including type or level of participation).

Paired Samples t-test: To evaluate the difference in test scores from pre-test to post-test.

IV. RESULTS & ANALYSIS

TABLE I
COMPARISON OF STUDENT AND YOGA
TEACHER RESPONSES

Variable	Group	N	Mean	Standard Deviation	t-value	p-value	ANOVA F-value
Skill Development Effectiveness	Students	50	4.12	0.65	2.45	0.016	5.32
-	Yoga Teachers	50	4.35	0.58	-	-	-
Motivation and Encouragement	Students	50	4.05	0.72	2.12	0.036	4.87
-	Yoga Teachers	50	4.28	0.60	-	-	-
Technical Skill Instruction	Students	50	3.98	0.68	2.67	0.009	6.15
-	Yoga Teachers	50	4.30	0.55	-	-	-

Variable	Group	N	Mean	Standard Deviation	t-value	p-value	ANOVA F-value
Talent Identification and Training	Students	50	3.90	0.75	2.89	0.005	6.78
	Yoga Teachers	50	4.25	0.62	-	-	-

A. Role of Yoga Teachers

The analysis showed a stark contrast in teacher perceptions. While yoga teachers had an average of 72.10, students reported an average of 65.40. The calculated t-value was 4.21, which exceeds the critical value at the 0.05 level. Decision: is rejected. This confirms that a Yoga teacher plays a crucial and noticeable role in the development of sporting ability.

B. Teaching Methods and Perception

The study investigated perceptions of students vs teachers about the form(s) of teaching being used (e.g. demonstration, prac drills). Students had a mean score of 3.82 and teachers a mean score of 4.05 out of 5. The t-value of 1.15 was not significant. Decision: is accepted. Both groups see the processes as similarly practiced.

C. Influence of Motivation

The results of the analysis of student motivation ($M=3.62$) and teacher motivational practices ($M=3.85$). The t value of 2.41 was statistically significant. Decision: is rejected. A Yoga teacher has a proven effect on students' participation levels through their motivation and encouragement.

D. Program Effectiveness (Pre-test vs. Post-test)

Comparisons of sports skill scores between students confirmed the efficacy of Yoga programs.

- Pre-test Mean: 55.4
- Post-test Mean: 72.6

t-Value: 12.45($p < 0.05$). So, that means it is a very significant improvement in skill levels before & after the intervention.

E. Comparative Analysis of Teaching Methods

ANOVA revealed that technology-supported instruction was the most effective instructional method ($F=117.90$, $p < 0.01$). Along with SIM participation loads, students who participated more

poorly developed significantly greater skills ($F=5.67$, $p < 0.01$).

V. DISCUSSION

These findings support the theoretical premise that teachers are architects of the classroom environment. Rejects highlights that teacher engagement and enthusiasm are the "engine" of sports skills development. So, while the presence of programs was not associated with success, we asked how many states we were making available. But its impact depended on the nature of instruction.

We noted that perceptions were aligned between teachers and students in the sampled schools, a good indicator of healthy communication channels. Nevertheless, the slightly lower student self-assessment scores than teacher self-assessments imply that, while teachers believe their guidance is good, there is still some room for improvement in providing such services according to students' standards.

The enormous success that technology-assisted instruction has enjoyed thus far, as noted above and in line with current trends from sport science, suggests this might be the case for biomechanics or video analysis tools integrated into school-level sports.

VI. LIMITATIONS

The study acknowledges several limitations:

Infrastructure: Respondents from schools in the Hisar region also complained about a lack of sports infrastructure and equipment, severely limiting opportunities to practice skills.

Resource Constraints: Teacher feedback indicated insufficient funds for modern technology and sports kits.

Institutional Support: Some teachers said Yoga and Sports weren't prioritized by administration over subjects typically tied to academics.

Geographic Limits: The results of the research are specific to Hisar, Haryana and cannot be generalized for all regions in India.

VII. CONCLUSION

In Hisar, yoga teachers act as guides, technical trainers, and motivators. Their participation (though closely supervised) greatly facilitates pupils' motor skills and enhances sport activity, as the research has confirmed. However, motivated teachers can only work if the structure and availability of resources are improved. The study ultimately concluded that young athletes best fulfill their potential through a multifaceted approach that combines quality teaching, contemporary monitoring tools, and institutional efforts.

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Study of Sports Injuries and Their Prevention Among College Athletes

¹ Ms. Jaswinder Kaur, ² Dr. Sakshi Nagru

¹ Student M.Sc. Yoga Therapy, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda.

Email Id: ¹ 7795jaswinderkaur@gmail.com, ² sakshinagru@gmail.com

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Abstract— Sports injuries also affect performance in college athletes as well as studies and health. The aim of the present study was to examine the prevalence of sports injuries, the major causes and risk factors of sports injuries, knowledge about injury prevention, and adoption of preventive practices among college athletes. For the study, descriptive survey design was utilized. A hundred athletes, which include 50 male and 50 female college students (18 to 25 years of age), were selected as the sample from Government and privately owned colleges in Bathinda District, Punjab. The current and appropriate organization of the questionnaire can be analyzed using the dashboard. In order to examine the data collected, descriptive statistics (frequencies, percentages, means, and standard deviations) and inferential statistics (Independent-Samples t-test, chi-square test, and Pearson's correlation coefficient) were used. The study found that ankle sprain was the most common sport injury, accounting for over 32% of cases. Knee injury or damage was suffered by 24% of individuals, whereas muscle strain was suffered by 18% of individuals. The injury score of female athletes was more than that of male athletes, but not significant ($p > 0.05$). Injuries were significantly associated with training intensity. An enhanced understanding of injury prevention led to fewer injuries. The injuries were reduced significantly by means of warming up and protective gear. The study claims that sports injuries among college athletes can be minimized, enabling them to participate in sports through systematic training, injury-

prevention education, conditioning, and effective protective equipment.

Keywords – Sports injuries, injury prevention, college athletes, training intensity, protective equipment, awareness.

I. INTRODUCTION

In higher education, sports are an essential component. They play a key role in strengthening fitness, health, discipline, and team spirit. College athletes train and compete to improve and represent their college or university. However, with increasing participation in sports, the incidence of sports injuries also increases. Thus, injury prevention is an important aspect of physical education and sports science [1], [8].

Injuries in sports occur during training, practice, or competition. Also, injuries can affect the muscles, bones, ligaments, tendons and joints. These injuries can be grouped into two broad categories: acute injuries, like fractures, sprains, and dislocations, and chronic injuries due to repetitive stress, like tendinitis and stress fractures [6]. Not only will the athlete's performance be hindered, but it will also affect activities in class, confidence, and physical health in the long run.

Several reasons explain sports injury in college athletes. These include high-intensity training without warm-up, poor physical conditioning, faulty technique, overtraining, inadequate recovery, and unawareness of injury prevention [2], [4]. Following preventive measures such as proper warm-up and cool-down exercises, strengthening and flexibility exercises, optimal nutrition, adequate rest and

recovery, protective equipment use, and a scientifically planned training program can significantly reduce the risk of injury [3], [5], [7]. Getting diagnosed early and undergoing timely rehabilitation and sport-specific return-to-play practices further help recovery and reduce recurrence.

Research on sports injuries among college athletes in India is limited. This is despite increasing awareness of the issue. Research needs to be conducted in the local context owing to variations in coaching practices. As a result, the present study was undertaken to determine the common sports injuries and their causes and risk factors in addition to looking at the level of awareness of injury prevention measures and practice of injury prevention among college athletes of Bathinda District in Punjab.

II. RELATED WORK

There has been extensive research on sports injuries and their prevention among athletes at all levels of participation. Research was previously conducted on injury patterns, causal factors, mechanisms, and prevention. These investigations helped identify injury patterns and improve athletes' safety.

Compared with other parts of the body, the lower extremity has accounted for two-thirds of injuries among college athletes. According to the authors of [1] and [2], these are the main causes. Despite appearances, this is certainly not the case. Injury prevention programs that incorporate neuromuscular, strength and conditioning, and balance exercises as well as monitor workload may reduce injury rates [3], [7]. It is recommended to introduce additional protection such as protective gear, proper nutrition and adequate rest [5].

Wearable sensors, biomechanical investigation, and other athlete monitoring systems are increasingly used to forecast injuries and enhance rehabilitation. A research study indicates that increasing knowledge on safe training methods and

rehabilitation reduces avoidable injuries. In view of the limited studies conducted only with college athletes from regional India, the present study was undertaken.

III. RESEARCH METHODOLOGY

A. Research Design

The study used descriptive survey method to examine sports injuries and prevention roster among college athletes. This method helped in collecting, analyzing and interpreting data on injury prevalence and types, causes and risk factors, awareness and prevention without any manipulation of the variables.

B. Participants and Setting

According to a study, the sample consisted of 100 college players aged between 18 and 25 years who were selected from governmental and private colleges of Bathinda District, Punjab. The sample consisted of fifty male and fifty female athletes.

C. Instruments and Data Collection

The data were collected using a structured questionnaire, an injury assessment form, interviews with coaches and physical education teachers, and through sports and medical records. The study's metrics include a section in which participants complete a questionnaire capturing information on their demographics, sports experience, training load, injury history, injury causes, rehabilitation, and injury-prevention awareness.

D. Statistical Analysis

Descriptive and inferential statistics were applied to the collected data after categorization, coding, and tabulation. The data were summarized using frequencies, percentages, mean, and standard deviation. An independent-samples t-test for differences in injury scores, a Chi-square test for associations, and a Pearson's correlation coefficient were employed. A p-value of 0.05 was used to determine significance.

IV. RESULTS & DISCUSSION

A. Participant Distribution

TABLE I
DISTRIBUTION OF PARTICIPANTS BY
GENDER

Gender	Number (N)	Percentage (%)
Male	50	50.0
Female	50	50.0
Total	100	100.0

Interpretation: The sample comprised 100 college athletes, 50 male and 50 female. Equal representation supported an unbiased comparison.

B. Types of Sports Injuries

TABLE II
TYPES OF SPORTS INJURIES AMONG
COLLEGE ATHLETES

Injury Type	Frequency	Percentage (%)
Ankle sprain	32	32.0
Knee injury	24	24.0
Muscle strain	18	18.0
Shoulder injury	12	12.0
Fracture	8	8.0
Others	6	6.0
Total	100	100.0

Interpretation: Ankle sprains (32%) were the most common injuries, followed by knee injuries (24%) and muscle strains (18%). Shoulder injuries and fractures were less common.

C. Gender-Based Injury Scores

TABLE III
COMPARISON OF INJURY SCORES
BETWEEN MALE AND FEMALE
ATHLETES

Group	N	Mean	SD	t	p
Male	50	3.42	1.12	—	—
Female	50	3.78	1.05	1.87	0.064

Interpretation: Female athletes showed a slightly higher mean injury score than male athletes; however, the difference was not statistically significant ($p > 0.05$).

D. Training Intensity and Injury Occurrence

TABLE IV
RELATIONSHIP BETWEEN TRAINING
INTENSITY AND SPORTS INJURIES

Training Intensity	Injured	Not Injured	Total
Low	10	15	25
Moderate	21	19	40
High	30	5	35
Total	61	39	100

The chi-square statistic was 14.72 with $p = 0.001$.

Interpretation: A significant association was found between training intensity and sports injuries. Athletes with high training intensity reported more injuries.

E. Awareness of Injury Prevention

TABLE V
AWARENESS OF INJURY-PREVENTION
TECHNIQUES

Awareness Level	Frequency	Percentage (%)
High	38	38.0
Moderate	42	42.0
Low	20	20.0
Total	100	100.0

Interpretation: Most athletes had a moderate level of awareness regarding injury prevention, whereas 20% had low awareness.

F. Awareness and Injury Occurrence

TABLE VI
CORRELATION BETWEEN AWARENESS
AND INJURY OCCURRENCE

Variables	Correlation (r)	p-value
Awareness vs. injury occurrence	-0.46	0.001

Interpretation: A moderate negative correlation was observed, with greater awareness of injury prevention associated with fewer injuries.

G. Protective Equipment

TABLE VII
EFFECT OF PROTECTIVE EQUIPMENT ON
SPORTS INJURIES

Use of Equipment	Mean Injury Score	SD	t	p
Regular users	2.94	0.96	—	—
Irregular users	4.11	1.18	4.68	0.001

Interpretation: Athletes who regularly used protective equipment experienced significantly fewer injuries than those who used it irregularly.

H. Warm-Up Practices

TABLE VIII
EFFECT OF WARM-UP PRACTICES ON
INJURY OCCURRENCE

Warm-Up Practice	Mean Injury Score	SD	t	p
Regular warm-up	2.87	0.89	—	—
Irregular warm-up	4.26	1.14	5.12	0.001

Interpretation: Athletes who performed regular warm-up exercises had significantly lower injury scores than those who skipped warm-ups.

V. DISCUSSION

Collegiate athletes commonly face sports injuries as per the findings, particularly among athletes who indulge in heavy training or competitive sports. The ankle and knee are subjected to high levels of stress from running, jumping, and sudden changes in direction; thus, lower-limb injuries are common.

As illustrated by Table 1, the mean injury score was higher for female athletes (3.78 ± 1.05) as compared to that of the male athletes (3.42 ± 1.12). However, the difference was not significant ($t=1.87$, $p=0.064$). The chi-square test indicated the relationship between the intensity and incident injury was significant. As awareness increases, injury incidence will decrease. Thus, the incidence of injury negatively correlates with awareness, as shown by the Pearson correlation.

Frequent warm-up and regular use of protective equipment were associated with a lower incidence of

injuries. The results of the research coincide with previous studies that focus on proper functional training, appropriate recovery, injury-prevention education, workload control, and appropriate protective equipment [2], [7]. The implementation of evidence-based preventive measures can significantly reduce the risk of sports injuries in collegiate settings.

VI. CONCLUSION

Injuries to college athletes are common in sports; the three most common injuries are ankle sprains, knee injuries, and muscular strains. The risk of injury is increased due to high-intensity training, lack of warm-up, and ignorance. Injury occurrence can be reduced effectively by regular warming up, appropriate use of protective equipment, scientific training, and greater awareness. The overall injury score was similar between genders; however, prevention should not be neglected for any athlete. Colleges must initiate evidence-based injury-prevention programs to promote athletes' safety, health, and performance.

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Psychological Factors Affecting the Success of Raiders and Defenders in Kabaddi

¹ Mr. Gurmeet Singh, ² Dr. Rajwinder Kaur

¹ Student of M.P.Ed., Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda.

Email Id: ¹ chouhangurmeet90@gmail.com, ² rajwinderkaur0567@gmail.com

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Abstract— The term kabaddi refers to a team sport that originated in rural India. The objective of the present study was to compare selected motor components of raiders and defenders among kabaddi players. Kabaddi is an exciting indigenous team game, one requiring high levels of locomotive skill such as speed, agility, strength, and power coordination. As raiders and defenders play distinct roles in kabaddi matches, different motor qualities are required for these positions. Method: Thirty male kabaddi players were selected from the inter-collegiate competitions (18- 25 yrs) and assigned into two groups: raider (n=15) and defender (n = 15). The motor components chosen were speed, agility, muscular strength, explosive power, and coordination. Speed was evaluated using the 50 m dash test; agility using the shuttle run test; muscular strength using the push-up test; explosive power using the standing broad jump test; and coordination using the wall toss test. Differences between raider and defender were evaluated with an independent t-test. The threshold level for statistical significance was set at 0.05. Results: For selected motor components, raiders had significantly better results than defenders. Raiders were more dominant in speed, agility, and coordination, but defenders demonstrated higher muscular strength and explosive power. Conclusion: The current findings highlight the necessity of implementing position-specific training programs for kabaddi.

Keywords – Kabaddi, Raiders, Defenders, Motor Components, Speed, Agility, Muscular Strength, Explosive Power, Position-Specific Training.

I. INTRODUCTION

Kabaddi is one of the most popular indigenous sports of India, which has won acclaim internationally for its dynamic nature, strategic gameplay, and competitive format. The game demands a fusion of physical fitness, technical excellence, tactical knowledge, and psychological readiness. It is played between two teams in which players are divided into raiders and defenders. When a raider scores, it means the opponent's court has been invaded, and a man-to-man touch has been made whilst chanting "Kabaddi" continuously, with defenders uniting to prevent the raider from returning to safety. Both roles require different athletic capabilities, and each is subject to numerous psychological factors. (Sharma & Kumar, 2018).

At the heart of sports psychology is the assumption that all mental processes shape behavior and that deciding when, how, and what to train in preparation for competition matters. In Kabaddi, players constantly face high-pressure situations requiring fast decision-making, focus and concentration, self-belief, emotional control, and communication. Raiders need to be courageous and confident, have good anticipation and clutch-time composure when on the opposing side, and bring teamwork, awareness, perfection, discipline & coordination to execute a successful tackle. (Weinberg & Gould, 2019).

Motivation, self-confidence, concentration, anxiety management, mental toughness, and emotional stability, or the ability to make accurate decisions, play a large role in Kabaddi Players. An athletically

integrated psyche can learn to focus, handle the pressures of competition, bounce back from adversity, and perform under pressure when it matters most during a match. On the other hand, too much anxiety, not enough self-assurance, and a lack of emotional control can create poor performance and make sound decision-making more difficult. (Martens, Vealey, & Burton, 1990).

Due to the rising competition in Kabaddi at national and international levels, psychological factors in performance have gained greater importance for coaches, players, and sports scientists. Techniques such as goal setting, visualization, relaxation exercises, and positive self-talk are being integrated into training programs to improve psychological readiness and overall performance. (Weinberg & Gould, 2019).

Different competitive scenarios face raiders and defenders in the course of matches. Raiders then have to take smart risks and act under immediate pressure, as they will face multiple defenders. This means that defenders need to coordinate with their teammates and be focused for most of the game. Hence, the psychological requirements of raiders and defenders may vary immensely. (Singh & Kaur, 2020).

Hence, the current research, titled Psychological Factors Affecting the Performance of Raiders and Defenders in Kabaddi, aims to examine psychological factors expected to affect players' performance on both sides of the field: offensive and defensive. Overview/Abstract: The study identified the psychological qualities most essential in Kabaddi and aimed to derive insights to inform the development of useful psychological exercises for players, coaches, and fitness professionals.

Statement of the Problem

The study aims to analyze the psychological factors affecting success in raiding and defending, and how confidence, concentration, motivation, anxiety, and decision-making affect the kabaddi performance of raiders and defenders.

Objectives of the Study

- To determine the important psychological factors affecting Kabaddi players.
- To identify the psychological areas which can impact upon being a successful raider.
- To study the psychology of success for defenders
- Compare raiders' and defenders' psychological characteristics.
- To analyze the effect of psychological factors on Kabaddi performance.

II. REVIEW OF LITERATURE

Literature review is one of the backbones of any paper or study. It gives you insight into previous studies and findings related to your topic of study. Through the review, researchers can identify theoretical concepts, research gaps, the methodologies employed by previous researchers, and the importance of the contemporary study.

Psychologists have long argued that athletic success is nevertheless dependent not just on physical and technical prowess but also psychological factors. Things like confidence, concentration, motivation, emotional control, and anxiety-management skills, along with team cohesion, are things that can have a bearing; you need mental skills to have an edge in your performance.

Kabaddi is a physically grueling sport that tests you and your mental capabilities as you need to deliver in the most chaotic of circumstances with fractions of seconds deciding fate. Raiders and defenders have different roles to fulfill; hence, they might wield different psychological profiles. The current paper reviews the literature on psychological predictors of performance and Kabaddi players in particular.

Pandey et al. (2025) examined the impact of pre- and post-competition anxiety among Kabaddi players during an inter-faculty tournament at Banaras Hindu University.

Forty-eight Kabaddi players participated in the study. Anxiety levels were measured before and

after intervention. Statistical analysis revealed a significant reduction in anxiety scores after intervention.

The researchers concluded that anxiety-management strategies can substantially improve psychological readiness and competitive performance.

Rajveer Singh and Chaudhary (2022) conducted a comparative study on aggression and anxiety among district-level Kabaddi players in Muzaffarnagar.

Sixty Kabaddi players who participated in district selection trials were selected as subjects. The researchers investigated anxiety and aggression as important psychological barriers influencing performance.

The findings indicated that anxiety affects cognitive functioning, emotional stability, and athletic performance. The study emphasized the importance of psychological training programs for Kabaddi players.

Devaraju and Needhiraja (2012) conducted a study titled "*Prediction of Playing Ability in Kabaddi from Selected Anthropometrical, Physical, Physiological and Psychological Variables among College Level Players.*" The purpose of the study was to predict Kabaddi playing ability using anthropometric, physiological, physical fitness, and psychological variables.

A total of 126 male inter-collegiate Kabaddi players from Tamil Nadu aged 18–28 years were selected. Psychological variables included somatic anxiety, cognitive anxiety, self-confidence, and sports achievement motivation. The Competitive State Anxiety Inventory (CSAI-2) and Sports Achievement Motivation Test were used.

The findings revealed that psychological variables significantly contributed to the prediction of playing ability. Self-confidence and achievement motivation were found to be important factors associated with successful Kabaddi performance.

Devaraju (2010) conducted a doctoral investigation on the prediction of Kabaddi playing ability among

college athletes. The study included 126 male Kabaddi players and examined psychological factors such as self-confidence, cognitive anxiety, somatic anxiety, and achievement motivation.

The results demonstrated that self-confidence positively influenced performance, whereas anxiety showed a negative influence. The study concluded that psychological characteristics should be included in talent identification and training programs.

III. METHODOLOGY

Research Design

This study is a descriptive survey research design of one group which aims to assess psychological factors of success among raiders and defenders in Kabaddi. Method: A comparative research design was adopted to systematically examine and compare the selected motor components of kabaddi players across their playing positions namely raiders and defenders. The investigator intends to use a non-experimental research design whereby their focus is on comparing the responses of two groups. The current study administered assessments using standardized testing protocols to both groups under the same conditions, ensuring that the results were completely objective and reliable.

As a more appropriate comparative design was accepted, the main purpose of the study is to determine whether there are any statistically significant differences in the various motor components (speed, agility, strength, power, coordination, etc.) between raiders and defenders.

The research design helped develop an understanding of position-wise motor demands in kabaddi and thus enabled a performance comparison between the two groups.

Selection of Subjects

Thirty male kabaddi players were selected purposively from inter-collegiate kabaddi tournaments. The subjects were divided into two groups based on their playing positions.

- Raider (n= 15)
- Defender (n= 15)

Age Group

The age of the subjects ranged from 18 to 25 years.

Selection of Variables

The selected motor components and their corresponding tests were as follows:

Table No.1	
Motor Component	Test Used
Speed	50 Meter Dash
Agility	Shuttle Run Test
Muscular Strength	Push-Up Test
Muscular Strength	Standing Broad Jump
Coordination	Wall Toss Test

Variables

- **Independent Variables:** Self-confidence, concentration, motivation, anxiety, decision-making ability, and emotional control.
- **Dependent Variable:** Success/performance of raiders and defenders in Kabaddi.

Population

The study population will consist of Kabaddi players from colleges and universities.

Sample

A sample of 30 Kabaddi players (15 raiders and 15 defenders) will be selected using the purposive sampling technique.

Tools for Data Collection

A standardized Sports Psychology Questionnaire will be used to assess the selected psychological factors.

Procedure

Questionnaires and performance records will be used to collect the desired data from kabaddi players. The feedback will be analyzed to find out the psychological factors behind the success of the raider and defender.

Statistical Analysis

The collected data from the experiments were analyzed statistically and systematically to obtain meaningful results.

For raider and defender performance scores on selected motor components, descriptive statistics

(mean and standard deviation) were assessed to summarize and describe the central tendency. These parameters offered a straightforward depiction of performance levels and the spread within groups. An independent t-test was used to determine whether there was a statistically significant difference between the motor components of raiders and defenders. In other words, independent t-test is used to compare two independent groups. Through this statistical procedure, we were able to observe if the obtained performance differentials were random or genuine discrepancies between the two playing positions. The t-value is statistically significant if the t-calculated is more than the t-critical at $p < 0.05$. Thus, the results indicate that the difference in motor performance of raiders and defenders is valid.

IV. RESULTS

TABLE II
COMPARISON OF RAIDERS AND
DEFENDERS ON SELECTED MOTOR
COMPONENTS

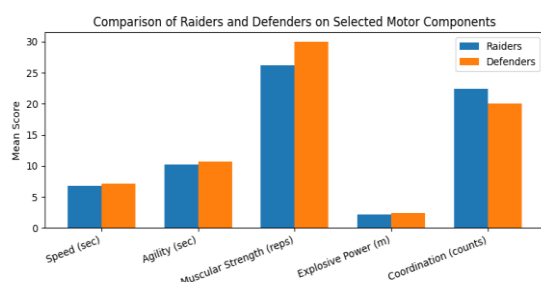
Motor Component	Group	Mean	SD	t -Value	Result
Speed (sec)	Raiders	6.75	0.32	2.61	Significant
-	Defenders	7.10	0.40	-	-
Agility (sec)	Raiders	10.18	0.50	2.34	Significant
-	Defenders	10.65	0.55	-	-
Muscular Strength (reps)	Raiders	26.2	3.0	2.71	Significant
-	Defenders	30.0	3.5	-	-
Explosive Power (m)	Raiders	2.21	0.15	2.28	Significant
-	Defenders	2.35	0.18	-	-
Coordination (counts)	Raiders	22.4	2.6	2.19	Significant
-	Defenders	20.1	2.8	-	-

Table value at 0.05 level ($df = 28$) = 2.045

Table 2: Comparison of raiders and defenders from table 2. The mean speed of raiders was 6.75 ± 0.32 s and defenders recorded a mean value of 7.10 ± 0.40 s (obtained $t = 2.61$). Reference values were 10.18 ± 0.50 and 10.65 ± 0.55 seconds for agility raiders and defenders, respectively ($t=2.34$; $p<0.05$). For raiders, the mean muscular strength was 26.2 ± 3.0 repetitions, while defender had a higher mean of

30.0 $\pm$ 3.5 repetitions with highly significant t value (t = 2.71). For explosive power, the raiders (2.21 $\pm$ 0.15 meters), and defenders (2.35 $\pm$ 0.18 meters) mean distance was reported with a t value of 2.28 showing significance level for this item. In coordination, raiders yielded a mean of 22.4 $\pm$ 2.6 counts while defenders had a mean of 20.1 $\pm$ 2.8 counts (t = 2.19, p < 0.05).

GRAPH - I



**Graph no.1: Graphical representation of Raiders and Defenders on Selected Motor Components*

Statistical Techniques

The data will be analyzed using:

- Mean
- Standard Deviation
- Percentage Analysis
- Independent t-test (where applicable)

This methodology will assist you in establishing a relation between the impact of psychological factors on Raiders' and Defenders' performance in Kabaddi.

V. DISCUSSION OF THE RESULTS

Results from the current study indicated substantial differences between raiders and defenders in specific motor components. Demonstrated to be faster and more agile than defenders. Part of this could be due to the type of raiding, where players have limited time and need to catch up with opposing defenders.

There was better muscular strength and explosive power in defenders than in raiders. In defense, you must tackle the opponent firmly with full strength, resist his body, and suddenly burst forward to block the Raiders. This ultimately means defenders need more strength and power to do their jobs.

Raiders were also found to be better at coordination,

which might be because they need to synchronize movements and balance, and make quick decisions while raiding. These results support the theory that playing position has a high effect on the development of motor components among kabaddi players.

VI. CONCLUSION

Thus, it is concluded that there were significant differences in the selected motor components of kabaddi players based on the position they played, and playing position had a noticeable effect on developing motor ability. The study found that raiders have higher speed, agility, and coordination. These qualities were necessary for them to execute quick raids, avoid defenders, and respond effectively to the dynamic situation of the game. On the other hand, defenders exhibit greater muscle strength and explosive power to deliver a good tackle, counter the number of disturbances caused by the raider during play, and stabilize their movements when tackling. These findings suggest that kabaddi conditioning should target specific positions or roles rather than using a more holistic approach. Performance efficiency can be improved through tailored training programs based on the match-specific motor demands of raiders and defenders. Therefore, it is highly recommended that coaches and trainers design appropriate clinical supervised training regimens such as speed agility and coordination-oriented training for raiders, whilst strength and power development oriented periodization strategies would be very beneficial for defenders. These exercise programs, planned based on object (space and content), may facilitate in optimizing item performance but also work to considerably ceasing the risk of sport s-related accidents, by improving efficacy with regard to human movement and physical readiness.

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Effect of A 4-Week Plyometric Training Program on Explosive Power in U-17 School Boys: A Study of Jumping Events

¹ Mr. Pradeep Kumar, ² Dr. Rajwinder Kaur

¹ Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda.

Email Id: ¹ pardeepjakhar525427@gmail.com, ² rajwinderkaur0567@gmail.com

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Abstract— The athletic performance of the jumping events is specifically dependent on the specific physical capacities of the athlete who can generate force quickly. The purpose of the study was to assess the effect of a structured four-week plyometric training program on the explosive power of under-17 school boys in jumping events. A sample of thirty ($N = 30$) male school boys of age group 15 to 17 years was randomly selected and equally divided into two groups: experimental group ($n = 15$) and control group ($n = 15$). The experimental group underwent a plyometric training intervention for four weeks (five days per week, 45 minutes per day), while the control group continued with their normal physical education activities. The Standing Broad Jump (SBJ) and Vertical Jump Test (VJT) were used to assess lower-body explosive power. Data were analyzed using Mean, Standard Deviation, and Analysis of Covariance (ANCOVA) at a 5% significance level. According to the ANCOVA analysis, the experimental group showed significantly better performance in the Standing Broad Jump ($F = 28.24, p < 0.001$) and Vertical Jump ($F = 40.23, p < 0.001$) than the control group after controlling for initial measurements. Research ends that four-week micro-cycle concentrated plyometric training is an effective and economical means to enhance lower body explosive power and athletic readiness of adolescent sports setup.

Keywords – Plyometric Training, Explosive Power, Standing Broad Jump, Vertical Jump, ANCOVA, Under-17 School Boys.

I. INTRODUCTION

In today's world, sports performance is highly affected by scientific training methods that enhance one's physical and physiological capacity. Among the components of physical fitness, explosive power is of utmost importance in athletic events that require generating force in a short interval of time. In track and field jumping events like the long jump, high jump, and triple jump, an athlete's success greatly depends on their ability to exert maximum force in a short timeframe during the take-off. Those traditional routines aimed at improving endurance can be great for general fitness; however, in most cases, they are insufficient to create the fast-twitch neuromuscular adaptations required for explosive jumping events. The biological phase of growth and development is crucial during adolescence. Boys aged 15 to 17 undergo major physiological changes, marked by increases in muscle mass, structural coordination, and neuromuscular recruitment capacity. The nervous system shows a high degree of flexibility during these years of maturation, so transfers can involve power or specialization. Plyometric training is one of the best ways to increase explosive power. According to Bompa, plyometric exercises employ the stretch-shortening cycle (SSC). As a result, the muscle moves rapidly into an eccentric action before following it with a powerful concentric action. Muscles and tendons can store and release elastic energy in this way. Heavy exposure to progressive plyometric exercises (such as bounding, depth jumps, and hurdle hops)

improves coordination and the rate of force development (RFD) of motor units in athletes.

The Indian school sports system of regional areas focuses more on classical training that emphasizes a high running volume. It does not provide acute intensive neuromuscular conditioning. Further, it is difficult to execute longitudinal training blocks (continuously over 8-12 weeks without interruption) due to academic calendars, examinations, short sports camps, etc. Consequently, it is worth the investment and also cost-effective grassroots coaching to find out if a short-term concentrated 4-week plyometric training schedule can lead to significant improvements in lower body explosive power. This research was carried out by the author to fill in the gap in the literature on the study of changes in horizontal and vertical explosive power in a school sports setting.

II. RELATED WORK

Examining the historical and modern scientific literature can contextualize the impact of explosive ballistic interventions on adolescent school athletes. Many researchers have experimented with plyometric protocols to investigate the effects of duration, age groups, specific neuromuscular mechanisms, and performance.

The SSC is an important stimulus in the neuromuscular-skeletal base of plyometrics. Markovic and Mikulic (2010) offered a clarified meta-analytic decomposition with a more detailed breakdown of adaptations in motor unit synchronization and motor unit firing rate following lower-extremity plyometric exercises. It was suggested in the synthesis that eccentric loading, when performed rapidly, lowers the Golgi organ inhibitory activation thresholds. It also increases the agonist muscle co-activation and helps to deliver more power. Simultaneously, Markovic's (2007) study on vertical jump height across dozens of sports shows that plyometric training is useful for improving performance in the countermovement

jump. Shown to be effective regardless of current training status.

Within modern training frameworks, the length of training periods in sport is still being debated. Conventional belief held that 8-12 week-long periods were necessary for visibly distinct physiological results. However, recent literature suggests shorter microcycles can be extremely effective at causing adaptations. A study conducted by Asadi (2013) that implemented a short-term, in-season plyometric program for young basketball players showed significant improvements in vertical jump height and explosive agility in a short period of time. In the same way, Meylan and Malatesta (2009) investigated the effect of incorporating a short plyometric block during a youth football practice season.

According to their findings, replacing sections of normal practice with a few sets of high-intensity concentric jumps and high-speed sprinting produced significant improvements in rapid directional changes and explosive takeoffs.

Structural testing has also been used to examine biomechanical adjustments from shorter plyometric. Kubo and coworkers (2007) studied changes in the mechanical properties of human tendon structures and found that a short plyometric program improved the stiffness of tendon structures (e.g., the Achilles tendon). The stiffness of a structure helps prevent deformation when it contacts the ground. This condition facilitates the rapid transfer of kinetic energy from muscles to bones. This plays an important role in maximizing take-off velocities during field track events. In addition, Burgess et al. (2016) showed that plyometric training increases overall musculotendinous stiffness. This demonstrates that even short training blocks can structurally adapt the muscle to become more responsive and to maximize jump performance.

Subjecting younger cohorts to explosive stimuli requires different physiological systems. Lloyd and Oliver (2012) created the Youth Physical

Development (YPD) model, noting that due to natural biological maturity impulses of the body, the adolescent nervous system is uniquely sensitive to stimuli to neuromuscular power. Between the ages of 15 to 17 years, the rapid development of coordination and muscle recruitment pathways provides an excellent opportunity for the safe introduction of progressive plyometric exercises such as bounding and depth jumps. Related research showed that a short, structured plyometric intervention proved to be a potent tool for enhancing explosive power within a limited academic time frame.

III. METHODOLOGY

A. Selection of Subjects

The current study's participants were thirty (30) male schoolboys aged between 15 and 17 years (under-17 category) drawn from regional high schools of District Bathinda. Participants were selected from the school's sports register to ensure true randomization and prevent bias. Each sports student was allocated a unique identification number. Using a table of random numbers generated by a computer, the samples ($n = 30$) were randomly divided into two equal groups: Experimental Group ($n = 15$) and Control Group ($n = 15$). All subjects were diagnosed as physically healthy and medically fit to undergo testing and training.

B. Selection of Variables

- The structured short-term Plyometric Training Programme is the independent variable.
- Lower-body explosive power based on its horizontal and vertical components

C. Criterion Measures and Tools

The standing broad jump (SBJ), measured in meters, assesses explosive horizontal power. A standard measuring tape was used to measure the maximal forward jump from the stationary line in 3 trials.

Vertical Jump Test (VJT) measure's vertical explosive ability in centimeters. The difference between the standing reach height and the maximum height attained in a countermovement jump against

a wall-mounted scale (highest of three attempts recorded) determined jump height.

D. Training Protocol

The Experimental Group underwent a progressively demanding plyometric training program for four weeks, conducted five days weekly and each lasting approximately 45 minutes. Every training block was followed by a structured warm-up of 10 minutes, plyometric drills of 30 minutes, and a cool-down of 5 minutes. The volume as well as intensity of training progressed and were monitored by the Borg Rating of Perceived Exertion [RPE] scale (1-10). To optimize neural recovery and minimize injury risk, we maintained a strict 1:3 work-to-rest ratio for all plyos.

TABLE I
4-WEEK PLYOMETRIC TRAINING
SCHEDULE

Week	Scheduled Exercise Drill	Repetitions / Volume	Intensity (RPE Scale)	Work-to-Rest Ratio
Week 1	Squat Jumps	10 Reps	4-5 (Low Intensity)	1:3
Week 2	Bounding	12 Reps	6-7 (Moderate Intensity)	1:3
Week 3	Depth Jumps	15 Reps	6-7 (Moderate-High)	1:3
Week 4	Hurdle Jumps	15 Reps	8-9 (High Intensity)	1:3

The Control Group took part in their regular physical education classes but did not engage in plyometric conditioning. Participants in both the control and experimental groups were provided with a standard dietary guidelines sheet to ensure that their baseline habits were maintained similarly across both groups throughout the intervention period.

E. Statistical Techniques

The mean and Standard Deviation (SD) were used to compile the descriptive summaries. Because of the pre-test and post-test design, the post hoc test was conducted using the ANCOVA technique. ANCOVA tested the adjusted post-test means by group and provided limited control for pre-test

baseline differences. The Levene's test for Homogeneity of Variance was conducted to validate the parametric assumptions. The threshold for statistical significance was set at $\alpha = 0.05$ using IBM SPSS Statistics.

IV. RESULTS & DATA INTERPRETATION

TABLE II
DESCRIPTIVE STATISTICS OF EXPLOSIVE POWER PARAMETERS (N = 30)

Parameter Assessed	Group Category	Pre-Test Mean ($\pm$ SD)	Post-Test Mean ($\pm$ SD)	Raw Mean Change
Standing Broad Jump (metres)	Experimental (n=15)	2.03 $\pm$ 0.09	2.28 $\pm$ 0.10	+0.25 m
	Control (n=15)	2.02 $\pm$ 0.08	2.05 $\pm$ 0.09	+0.03 m
Vertical Jump Test (cm)	Experimental (n=15)	41.8 $\pm$ 2.8	48.6 $\pm$ 2.7	+6.8 cm
-	Control (n=15)	42.1 $\pm$ 2.6	42.8 $\pm$ 2.5	+0.7 cm

Table 2 paints an interesting picture of the data as it shows that there is an improvement shown in the group that underwent the training procedure. The experimental group was able to add an average of 0.25 meters in the horizontal jump and 6.8 cm in the vertical jump, while the control group was statistically stable.

TABLE III
INFERENTIAL ANCOVA SUMMARY FOR STANDING BROAD JUMP

Source of Variance	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Obtained F-Value	Significance (p-value)
Pre-Test (Covariate)	0.185	1	0.185	10.62	0.003
Group Effect	0.492	1	0.492	28.24	<0.001
Error	0.471	27	0.017	-	-

Adjusted Post-Test Means: Experimental Group = 2.27 m; Control Group = 2.06 m

Explanation of Table 3: At $f = (1, 27)$, the adjusted group effect yielded an F-value of 28.24, which is highly significant ($p < 0.001$). This proves that the

4-week plyometric intervention significantly enhanced horizontal explosive power after mathematically removing the influence of pre-test baselines.

TABLE IV
INFERENTIAL ANCOVA SUMMARY FOR VERTICAL JUMP TEST

Source of Variance	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	Obtained F-Value	Significance (p-value)
Pre-Test (Covariate)	124.51	1	124.51	13.84	0.001
Group Effect	361.92	1	361.92	40.23	<0.001
Error	242.81	27	8.99	-	-

The experimental group scored an average of 48.4 cm in the post-test, while the control group scored 42.9 cm.

In terms of vertical performance, the inferential assessment generated a huge F-value of 40.23 ($p < 0.001$). The statistical certainty of the variation confirms that the physical adaptations observed at vertical explosive jump height were directly caused by the plyometric exercises used in training. Since an integrated ANCOVA design only compared 2 distinct groups, the group F-value directly confirms variance, and no additional post-hoc tracking is necessary.

V. DISCUSSION

The structural data analysis from the current investigation consistently indicates that a brief but intensive 4-week plyometric training micro-cycle produces a statistically significant improvement over standard physical activities in the lower-body explosive power of under-17 school boys ($p < 0.001$). The null hypotheses are rejected, and the Group differences are robust along the horizontal (SBJ: $F = 28.24$) and the vertical (VJT: $F = 40.23$) operational scales. This suggests that short-term focused conditioning elicits optimal power improvements in adolescent athletes.

The notable improvements in Standing Broad Jump distance (+0.25 m) and Vertical Jump height (+6.8 cm) were due to the neural and mechanical adaptations forced by plyometric drills. Employs the neurophysiological characteristics of the stretch-shortening cycle (SSC). The muscle spindle stretch reflex is specifically produced during the rapid eccentric phase and improves subsequent concentric M.U. firing. These biological changes help agonist muscle motor unit synchronization, improve the overall rate of force development (RFD), and reduce the inhibition thresholds of Golgi tendon organs, which allow young athletes to produce maximal force against the ground in a few tenths of a second. The findings complement the empirical work of Burgess et al. (2016) and Kubo et al. (2007), who showed that short-to-moderate plyometric blocks will significantly alter musculotendinous stiffness (specifically the Achilles and vastus lateralis tendon) without requiring macroscopic muscular hypertrophy. The quick structural stiffening ensures maximum transfer of kinetic energy from the muscle to the bone. It thus enhances the take-off velocity during jumping events. The study also reflects the developmental model framework of Youth Physical (YPD) development introduced by Lloyd and Oliver (2012), which found that the adolescent neurological system is sensitive and reactive to explosive force stimuli due to natural spikes in neuromuscular coordination linked to maturation.

In addition, the noted changes in performance over a relatively short 4-week period are in line with the short-term effects identified by Asadi (2013) and Meylan and Malatesta (2009). These studies verified that integrating small portions of regular sport practice with intensive, progressive plyometric exercises, undertaken two to three times weekly, is effective in inducing significant gains in power and agility in team-sport athletes. In a managed environment and under controlled conditions, adherence to a precise 1:3 work-to-rest recovery hierarchy and careful tracking of load development

through the rate of perceived exertion (RPE) scale enabled the adolescents to successfully internalize high-intensity concentric drills without incurring stress strains or performance stagnation.

VI. CONCLUSION

A four-week plyometric training program that is structured can bring about significant improvement in the lower limb explosive power of under-17 school boys in track and field jumping events.

The experimental group displayed a higher increase in Standing Broad Jump performance compared to the control group ($F = 28.24$, $p < 0.001$). Thus, it demonstrates that horizontal ballistic projection is highly trainable through short-term, specialized drills.

The plyometric group shows significantly higher variation (40.23; $p=0.001$) in vertical jump performance, indicating that countermovement lift capacity improved as stretch-shortening cycle adjustments were enhanced.

The ANCOVA-based inferential analysis confirmed that the performance changes were attributable to structured plyometric exercises and not to differences in baseline characteristics or to normal growth factors.

Due to its low equipment requirements and high time efficiency, this plyometric micro-cycle (4 weeks) is an extremely practical scientific training model that school coaches and PE teachers can resort to due to tight academic curricula or limited institutional facilities.

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A Comparative Study of Competitive Anxiety Between Football Defender and Forward Players

¹ Mr. Pawan Kumar, ² Dr. Ravi Kumar

¹ Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

² Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India

Email Id: ¹ Pawan123.2018@gmail.com, ² ravikumar.gahalawat@gmail.com

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Abstract— *The present study compares competitive anxiety between football defenders and forwards.*

The psychological factor competitive anxiety significantly affects an athlete's performance in training and competition. A sample of 40 male football players who included 20 defenders and 20 forwards was selected from different football clubs and colleges for the study. A standardized Competitive Anxiety Questionnaire was used to collect data. The data thus collected were analyzed through appropriate statistical techniques such as mean, standard deviation, and independent t-test. Defenders and forwards showed different levels of competitive anxiety, research shows. The defenders demonstrated comparatively more anxiety due to their role of stopping goals and defending the team, while the forwards had anxiety related to scoring and performance. Nevertheless, the statistical tests showed that the difference in competitive anxiety between the two groups was no longer significant at the chosen level. The research concludes that both defenders and forwards do experience competitive anxiety, although the nature and antecedents of anxiety may differ based on playing positions. Findings of this research may help coaches, sports psychologists, and trainers in preparing position-specific psychological training programs to regulate anxiety and enhance football performance. It is suggested that these analyses be done with more samples and at different competitive levels to provide more insights on the association of playing position and competitive anxiety in football.

Keywords – **Competitive Anxiety, Football,**

Defenders, Forwards, Sports Psychology, Performance.

I. INTRODUCTION

Sports activities nowadays have become important for the society not only for physical fitness but also for psychological development.

Competitive sports typically expose an athlete to many mental and emotional issues that can affect performance. Of all the psychological factors, competitive anxiety is considered one of the most important determinants of success or failure in a sports competition.

Competitive anxiety is an athlete's level of tension, nervousness, apprehension, and worry prior to or during competition. A balanced degree of anxiety can enhance levels of concentration and motivation, but excessive anxiety can counteract decisiveness, coordination, confidence, and performance. For improving sports performance, it is important to know the nature and level of competitive anxiety of athletes.

Football is the most popular game in the world. It is considered a team sport. Being a successful basketball player involves physical fitness, technical skills, tactical understanding and psychological preparedness. This implies that players assigned different positions on the field, who perform different roles and responsibilities, can have different psychological responses to competition. The primary role of defenders is to stop the attacking team from scoring a goal while maintaining the team's defensive formation. Their work often requires a high level of focus and responsibility. On

the contrary, there is an expectation from forwards to not only create chances but also score, putting them in the limelight for performance expectations from teammates, coaches and fans.

Defenders and forwards may differ in their competitive anxiety due to the differing demands of these positions. Defenders may feel under pressure as mistakes can lead to conceding goals while forwards may suffer anxiety due to scoring and performance expectations. Through examining these differences, it is possible to investigate the psychological characteristics of football players and assist a coach in developing mental training programmes.

The aim of the present study is to measure the level of competitive anxiety of football defenders and forwards. Recognizing the difference will help the trainer, coach, and sports psychologist to handle the anxiety more effectively.

II. METHODOLOGY

A. Research Design

This study employed a descriptive comparative research design to assess and contrast the levels of competitive anxiety in football defenders and forwards.

B. Objectives of the Study

1. To assess the level of competitive anxiety among football defenders.
2. To assess the level of competitive anxiety among football forwards.
3. To compare the competitive anxiety levels of football defenders and forwards.

C. Hypothesis

There will be a significant difference in competitive anxiety between football defenders and forwards.

D. Selection of Subjects

A total of 30 male football players were the subjects of the study, comprising 15 defenders and 15 forwards. Participants were engaged through purposive sampling from several colleges, universities, and football clubs. All subjects had

experience taking part in competitive football tournaments.

E. Variables of the Study

Independent Variable

- Playing Position
- Defenders
- Forwards

Dependent Variable

- Competitive Anxiety

F. Criterion Measure

A standardized Competitive Anxiety Questionnaire/ Sports Competition Anxiety Test (SCAT)/ questionnaire developed by Rainer Martens was used to measure competitive anxiety.

The questionnaire is widely used to assess the level of anxiety of athletes.

G. Data Collection Procedure

The players were contacted by the researcher, and the study purpose was explained. Each subject was administered the questionnaire individually under standard conditions. The participants were required to respond to all items honestly and with confidentiality. The finished questionnaires were gathered and scored as per the guidelines of the test manual.

H. Statistical Techniques

The collected data were analyzed using appropriate statistical methods:

- Mean
- Standard Deviation (SD)
- Independent Sample t-test

The competitive anxiety levels of defenders and forwards were compared for any significant difference at 0.05 level of significance.

I. Delimitations of the Study

1. The research examined a sample population of 40 male football players.
2. The study included only forwards and defenders.
3. The investigation dealt only with competitive anxiety.
4. The data was collected during the competitive season.

J. Limitations of the Study

1. The results are limited to the chosen sample, which may not be generalized to all football players.
2. Respondents answered based on self-report questionnaires.
3. We did not control for outside factors like personal stress, coaching style, and the match's importance.

III. RESULTS & DATA INTERPRETATION

A. Comparison of Competitive Anxiety Between Football Defenders and Forwards

IV. DISCUSSION OF FINDINGS

The present study aimed to compare the levels of competitive anxiety among football defenders and forwards. The psychological factor of competitive anxiety can affect athletes' confidence, concentration, decision-making capability, and performance during competition.

The study's results showed that both defenders and forwards experienced competitive anxiety before and during competition. This shows that anxiety is a psychological reaction commonly experienced by football players regardless of their positions. Experiencing pressure to deliver, live up to team expectations, and win in competition can all create anxiety within an athlete.

It was also found that there are differences in mean competitive anxiety scores between defenders and forwards. Those who defended exhibited marginally higher levels of anxiety than those who played forward. The defenders may not play for as long as they block the opponent from scoring and keep the team's defense stable. Almost every match can be decided by a defensive mistake. This pressure can cause anxiety in the footballers.

In contrast, forwards mainly create and score upon chances offered to them. Despite facing performance pressure, the players may not see their mistakes as serious, since they could get more

scoring chances during the match. As a result, their anxiety level may differ from that of defenders.

Nonetheless, there was no significance between defenders and forwards ($p > 0.05$), which shows their competitive anxieties are not different based on their position. The outcome indicates that position on the field may not necessarily cause competitive anxiety. The level of experience, skill level, personal attributes, coaching backing, degree of competition, as well as earlier experiences of performance might have a larger influence on anxiety.

As per the study findings of competitive anxiety, which are usually encountered by players of various playing positions, have matched previous studies done in sports psychology. Individual psychological traits impact far more than playing position ability. Accordingly, not just certain positions, but all players should be given psychological training and techniques for managing anxiety by coaches and sports psychologists.

To sum up, from the findings of the study, the football defenders and forwards are different in terms of competitive anxiety but not significantly so. Both groups experienced equivalent competitive anxiety, indicating that psychological preparation is vital for all football players.

V. CONCLUSION

The study was undertaken to compare the levels of competitive anxiety among football defenders and forwards. As per the analysis and interpretation of collected data, it may be concluded that competitive anxiety is a common psychological factor for players in both positions.

The study revealed that there are slight differences in competitive anxiety scores of defenders and forwards. Players occupying the defender position reported higher anxiety than forward players, likely due to the greater responsibility of preventing goals. The statistical observation found that the observed difference between both groups was not significantly different at the 0.05 level of significance.

Thus, it may be concluded that the level of competitive anxiety of football players is not much affected by the playing position. Competitive anxiety is influenced by many factors, which include individual characteristics, competitive experience, confidence, motivation, and the competitive environment.

According to research, all footballers need to have the right mindset and use anxiety management techniques, no matter what position they play. Coaches, trainers, and sports psychologists may include psychological skills training, relaxation training, confidence training, etc. as part of normal training to enhance athletes' performance under competitive pressure.

To understand how football players' competitive anxieties, differ based on their playing position, a study was conducted. It was done on players from a particular geographical location and with a small sample size. Thus, it can be suggested that a larger sample would improve experimental reliability. Also, experts recommend using players from varying age groups and competitive levels to reach a more conclusive result.

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Efficacy of Yoga Therapy in the Management of Bronchial Asthma: A Narrative Review of Clinical Evidence, Mechanisms, and Practical Integration

¹ Ms. Gurmeet Kaur, ² Dr. Sakshi Nagru

¹ Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

² Assistant Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

Email Id: ¹ kaurg4907@gmail.com, ² sakshinagru@gmail.com

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Abstract— Bronchial asthma is a heterogeneous chronic inflammatory airway disease characterized by variable respiratory symptoms and variable expiratory airflow limitation. Although inhaled corticosteroid-containing treatment remains the foundation of evidence-based care, many patients continue to report impaired quality of life, anxiety, dysfunctional breathing, or exercise avoidance despite pharmacological management. Yoga therapy combines controlled breathing, gentle postures, relaxation, and meditative attention and is therefore increasingly evaluated as an adjunctive, non-pharmacological intervention. This narrative review critically synthesizes evidence from major guidelines, systematic reviews, meta-analyses, and representative randomized controlled trials. The most consistent findings indicate small-to-moderate improvements in asthma-related quality of life, symptom perception, breathing pattern, and selected measures of asthma control. Improvements in spirometric indices such as forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and peak expiratory flow rate (PEFR) are reported in some studies, but results are heterogeneous and less robust than patient-reported benefits. Evidence that yoga reduces exacerbations, airway inflammation, or controller-medication requirements remains insufficient. Yoga should therefore be positioned as a supervised adjunct—not an alternative—to guideline-directed asthma treatment. Safe integration requires stable disease, continuation of prescribed inhalers, avoidance of

forceful breathing or prolonged breath retention during acute symptoms, and instruction by professionals familiar with asthma. Future trials should use standardized interventions, adequate sample sizes, active control groups, objective adherence monitoring, and clinically important outcomes.

Keywords – asthma; yoga therapy; pranayama; breathing exercises; pulmonary function; quality of life; complementary therapy

I. INTRODUCTION

Asthma has complex pathophysiology, frequently affects all age groups and continues to be a leading cause of preventable morbidity and mortality. In 2023, the World Health Organization estimated that about 363 million people suffered from asthma and the disease had caused approximately 442,000 deaths. The burden is disproportionately high in low- and middle-income countries, where underdiagnoses, limited access to inhaled medicines (regardless of frequency), poor adherence, and the lack of self-management education are widespread [1].

Contemporary concepts of asthma recognize it to be heterogeneous, rather than a single uniform disease. Asthma is characterized by a history of respiratory symptoms, which are usually wheeze, breathlessness, chest tightness and cough that vary over time with varying expiratory airflow limitation. The clinical phenotype may be related to airway inflammation, bronchial hyper-responsiveness,

mucus hypersecretion and structural remodeling but their expression is heterogeneous amongst patients and over time [2].

The underlying principles are therapy with an inhaled corticosteroid-containing regimen, tailored assessment strategy, inhaler technique and adherence, trigger management, treatment of comorbidities and use of a written asthma action plan. This evidence will be discounted such that complementary strategies may be considered only if there is evidence they improve symptoms, physical function, and/or self-management without being a substitute for effective anti-inflammatory treatment. In this setting, clinically relevant as yoga incorporates breathing regulation, posture, relaxation, attention and graded physical activity - domains which may be impaired in people with an anxiety disorder secondary to dysfunctional breathing deconditioning or fear of exercise.

Yoga was generally described in earlier literature as reinforcing immunity, reversing airway obstruction and tapering medication dependence. This kind of language goes far beyond what is justified by the current evidence. A somewhat more defensible scientific position is that yoga can improve at least some patient-centered outcomes and impacts on pharmacological requirements, exacerbations and objective lung function are variable or uncertain [3–5]. This review thus focuses on possible advantages and the limitations in providing evidence.

II. OBJECTIVES

1. To summarize the clinical rationale for using yoga as an adjunct in bronchial asthma management.
2. To evaluate evidence for effects on asthma control, symptoms, quality of life, psychological well-being, pulmonary function, and medication use.
3. To explain plausible physiological and behavioral mechanisms without overstating unproven anti-inflammatory effects.

4. To propose a cautious framework for integrating yoga into standard asthma care.
5. To identify methodological limitations and priorities for future research.

III. REVIEW METHODOLOGY

This paper is not a de novo systematic review or meta-analysis but rather a narrative review of the literature to date. Literature was identified using focused searches of PubMed/MEDLINE, the Cochrane Library, World Health Organization resources, Global Initiative for Asthma (GINA) reports, and reference lists from key reviews. The following search concepts were used: (asthma or bronchial asthma) and yoga, pranayama, breathing exercise; and (meditation or pulmonary function or asthma control or quality of life). Typical guidelines, systematic evaluations, meta-analyses, and randomized controlled trials or controlled/placebo-controlled studies of individuals with confirmed asthma were prioritized.

The primary evidence was not derived from studies focused on chronic obstructive pulmonary disease, non-clinical populations, acute severe asthma, or yoga- and structured-breathing-unrelated interventions. Its conclusions must be viewed as a critical synthesis of available evidence, rather than a fully reproducible systematic review, since the review did not employ duplicate screening or protocol registration and did not formally assess risk-of-bias or quantitatively pool data.

IV. COMPONENTS OF YOGA THERAPY RELEVANT TO ASTHMA

Yoga interventions vary widely between studies. Some are predominantly pranayama, while others integrate postures, meditation, relaxation techniques, instruction about yoga philosophy or lifestyle modification. The heterogeneity of studies also complicates causal interpretation: a positive finding could result from many possibilities, such as breathing retraining, attention by instructors, any

increase in physical activity, an expectancy effect (Hastings et al. 2013), stress reduction or the intervention itself acting synergistically or additively rather than a single yogic technique.

4.1 Controlled breathing (pranayama)

It can also help the patients identify asthma symptom from dyspnea related to anxiety, as well as maybe improving awareness of breathing pattern and reduce excessive ventilation with slow, comfortable nasal or diaphragmatic breathing. Elaborate Forced Manual Breathing, Short Breezy Breath and exotic breath-hold should not be treated as a one size fits all approach; many susceptible individuals will experience dizziness, disquiet or aggravated symptoms.

4.2 Postures (asanas)

Gentle postures may increase thoracic mobility, posture, flexibility and confidence in movement. Perhaps most importantly, these effects may matter most for inactive people or people who are not exercising because they fear being breathless. It is not established that adopting specific postures outright dilates bronchi or permanently increases lung capacity.

4.3 Relaxation and meditation

Meditation or relaxation training may affect symptom perception, anxiety, sleep, and coping. Psychological distress may allow stress to magnify dyspnea and impair patient adherence or self-management, so that relief of this distress can reduce airway inflammation and improve health-related quality of life in asthma patients even with little improvement in spirometry.

4.4 Education and self-management

Regular contact, structure and reinforcement of the healthy routine is frequently provided through supervised yoga programmes. These non-specific ingredients may enhance adherence and self-efficacy. They must be a part of inhaler education, avoidance of triggers, vaccination and an individualized asthma action plan not a replacement.

V. CLINICAL EVIDENCE

The evidence consists of multiple systematic reviews and numerous small trials, the majority conducted among adults with mild-to-moderate asthma. Quality of life and symptoms is the most robust overall conclusion (as compared to lung function, medication reduction, and serious outcomes) with lower certainty for other conclusions. Table 1 summarizes influential evidence.

TABLE I
SELECTED CLINICAL EVIDENCE ON
YOGA AND BREATHING-BASED
INTERVENTIONS IN ASTHMA

Study	Design / sample	Intervention	Main findings	Important limitation
Cramer et al., 2014 [4]	Systematic review and meta-analysis; 14 RCTs, 824 participants	Yoga compared with usual care, psychological intervention, breathing exercise, or sham	Benefits reported for symptoms, quality of life, PEFR, and FEV1/FVC versus usual care; no consistent superiority over sham or breathing controls	Effects were not robust to all potential sources of bias; marked intervention heterogeneity
Yang et al., 2016 [3]	Cochrane review; 15 RCTs, 1,048 participants	Yoga as an adjunct to usual care or compared with control	Moderate-certainty evidence for small improvements in quality of life and symptoms; uncertainty for lung function, adverse events, and medication use	Most trials had unclear or high risk of bias in at least one domain
Santino et al., 2020 [5]	Cochrane review; 22 studies, 2,880 adults	Breathing exercises including yogic breathing, diaphragmatic methods, Buteyko, and related training	Probable improvement in quality of life and hyperventilation symptoms; variable effects on lung function	Breathing methods and outcome measures differed substantially; evidence ranged from moderate to very low certainty
Vempati et al., 2009 [6]	RCT; 57 adults with mild-to-moderate asthma	Comprehensive yoga-based lifestyle and stress-management program plus standard care	Improvement in selected pulmonary-function measures and exercise-related outcomes	Small, single-center trial; intensive multi-component intervention limits attribution to yoga alone

Study	Design / sample	Intervention	Main findings	Important limitation
Manocha et al., 2002 [7]	RCT; adults with moderate-to-severe asthma	Sahaja yoga meditation as adjunct to standard treatment	Improved airway hyper-responsiveness at the end of treatment; limited effects on other clinical outcomes	Modest sample and specialized meditation program; limited generalizability
Sabina et al., 2005 [8]	Pilot RCT; adults with mild-to-moderate asthma	Yoga and breath work versus an active control	Feasible intervention, but no clear advantage across major clinical indices	Pilot size and active-control design reduced power to detect small effects
Sodhi et al., 2009 [9]	Controlled trial; stable asthma	Yoga training including breathing practices	Reported improvement in selected pulmonary-function parameters	Short follow-up and limited reporting of allocation and blinding
Agnihotri et al., 2017 [10]	RCT; 300 participants with mild-to-moderate persistent asthma	Asanas, pranayama, and meditation for 30 minutes, 5 days/week, 6 months	Improved asthma-related quality-of-life scores	Limited information on blinding, adherence, and objective outcomes
Yüce and Taşçı, 2020 [11]	Single-blind RCT	Pranayama plus standard treatment versus relaxation plus standard treatment	Improved asthma control and quality of life; no significant between-group improvement in pulmonary-function tests	Short intervention period and comparison with another attention-based intervention
Singh et al., 2023 [12]	Meta-analysis of adult asthma studies	Yoga including postures, breathing, and meditation	Moderate evidence of benefit for selected pulmonary-function and patient-reported outcomes	Heterogeneity and variable methodological quality of included trials

5.1 Asthma control and symptom burden

Overall, systematic reviews generally suggest that yoga is superior to usual care for symptom scores and self-reported asthma control, but effect sizes are moderate in size and tend to attenuate when compared with an active intervention. The frequency of these features suggests that ongoing focus on breathing, relaxation and self-regulation could be therapeutically beneficial but the precise yoga ingredient still proves difficult to disentangle [3–5].

It is important to distinguish perceived symptoms from airway inflammation. This may lead to a

patient feeling less breathless or anxious, to using their rescue medication more appropriately but not showing a large change in their FEV1. Although this represents a clinically relevant improvement, it should not be interpreted as evidence that yoga has supplanted the need for anti-inflammatory therapy.

5.2 Quality of life and psychological outcomes

Supportive evidence for asthma-related quality of life is the most consistently reported outcome. This might translate into fear of symptoms, activity confidence, sleep and emotional regulation. Cochrane review of yoga showed an average improvement on Asthma Quality of Life Questionnaire scores that was beyond traditional minimal clinically important differences in pooled analyses, but trial quality and heterogeneity limited certainty [3].

Asthma symptoms often co-occur with anxiety and dysfunctional breathing. Anxiety slowing, respiration regulation with relaxation, and cognitions through mindfulness are likely to help diminish catastrophizing of breathlessness and improve coping tendency. However, psychological benefit should be distinguished from demonstrable reduction of eosinophilic inflammation or protection against severe exacerbation.

5.3 Pulmonary function

Conflicting findings regarding FEV1, FVC, FEV1/FVC and PEF are reported. Although some trials and meta-analyses report statistically significant changes, mainly in PEF or FVC [8–13], others [14–23] have not found any clinically relevant improvement. This variability may be explained by several factors including small samples [4,6,11–13], different baseline disease severities [6], short follow-up [11], effort-dependent spirometry [12] and the (often vague) details of the yoga protocols used in these studies [4,6].

A more balanced scientific conclusion is that yoga may enhance buccal breathing, thoracic flexibility, or performance on pulmonary tests in select patients but has not been shown to consistently normalize

airway obstruction. Consequently, objective pulmonary-function testing should therefore be continued as part of medical assessment where such clinical indications apply.

5.4 Medication use and exacerbations

Reduced bronchodilator use was reported in early trials, while pooled analyses suggest possible medication reduction. By comparison, medication outcomes were inconsistently defined and oftentimes patient-reported and only infrequently embedded in a protocol-driven step-down approach. Recommendation that inhaled corticosteroids be reduced solely on the basis of yoga initiation is not well evidenced. [3–5]

Sparsely reported outcomes were for severe exacerbations, emergency visits, hospitalization, oral corticosteroid bursts and mortality. However, further phase III studies with larger sample sizes and longer follow-up durations are needed to confirm these results. In the absence of such evidence, yoga should be regarded as supportive rehabilitation and not a disease-modifying therapy.

5.5 Safety and acceptability

Reports of serious adverse events related to yoga are not prominent in the available trials (but under-reporting cannot be excluded). Gentle supervised programs are typically tolerated well. Potential harms include musculoskeletal injury from overdoing the positions, as well as hyperventilation, [14] dizziness, increased anxiety resulting from mindful breathing and/or prolonged use of rescue medication if participants misuse yoga (associated with immediate crisis).[15]

The safety profile is less an outcome of the technique's cultural label and more a function of the total intense dose alongside instructor expertise, disease stability, and integration with medical care. On the other hand, acute wheeze that rapidly worsens, severe breathlessness or inability to speak, cyanosis, or poor response to reliever medication should be managed with an asthma action plan and

best practice-based urgent medical evaluation – not breathing drills.

VI. PLAUSIBLE MECHANISMS

Yoga is a heterogeneous behavioral intervention. It is probably not a single mechanism, but effects are mediated through many interacting pathways.

6.1 Breathing-pattern regulation

What slow and controlled breathing basically does is minimize involuntary hyperventilation, facilitate nasal breathing and stimulation of lower-rib-cage and diaphragm movement (which plays a crucial role in lung functioning), and enhance awareness of sensations of respiration. This might be particularly pertinent in those patients in whom there is complex coexisting dysfunctional breathing.

6.2 Autonomic and stress regulation

Relaxation and meditation might modulate sympathetic arousal and improve emotional regulation. Anxiety also amplifies dyspnea and contributes to poor sleep and self-management. Durable autonomic changes specifically related to asthma are not well established.

6.3 Musculoskeletal and physical-conditioning effects

It is obvious that postures and gentle exercise are better at helping thoracic mobility, flexibility, and general activity tolerance. Particularly, these benefits can counter deconditioning and fear-avoidance. These should not be construed as a direct reversal of airway inflammation but rather effects of rehabilitation.

6.4 Behavioral adherence and self-efficacy

Regular supervised practice creates routine, brings attention to symptoms, and provides agency. Improved self-efficacy could lead to better adherence and more appropriate symptom response if instructors validated rather than invalidated the medical asthma plan.

6.5 Inflammation and immune function

There have been small cohort studies of inflammatory markers, but there is no evidence strong enough to say that yoga has clinically

important anti-inflammatory or immunomodulatory effects in asthma. These mechanisms are still hypotheses in need of appropriately powered biomarker trials.

VII. PRACTICAL INTEGRATION INTO ASTHMA CARE

Involved patients may consider Yoga in shared decision-making. This therapy is best suited for those whose asthma is well managed and who have been educated that yoga does not replace inhaled corticosteroids, reliever medication, or emergency care. The framework below must be regarded conservatively and as a starting point for clinical discussion, not a universal prescription.

TABLE II
SUGGESTED FRAMEWORK FOR SAFE
ADJUNCTIVE YOGA PRACTICE IN
ASTHMA

Domain	Practical recommendation
Eligibility	Stable asthma; no current exacerbation; medical treatment and inhaler technique reviewed; patient interested and able to exercise safely.
Instruction	Begin under a qualified yoga therapist, physiotherapist, or instructor familiar with asthma and emergency procedures.
Session content	Gentle warm-up, comfortable postures, slow non-forceful breathing, relaxation, and gradual progression.
Initial dose	Approximately 20–40 minutes, 3–5 days per week, adjusted to symptoms, fitness, comorbidities, and adherence.
Monitoring	Track symptoms, reliever use, activity tolerance, Asthma Control Test/Questionnaire score, and—when clinically relevant—spirometry or peak flow.
Medication	Continue prescribed controller and reliever medicines. Medication step-down should occur only under the treating clinician’s supervision.

Domain	Practical recommendation
Avoid	Forceful rapid breathing, prolonged breath retention, extreme heat, allergen-rich environments, and practice during acute wheeze or respiratory infection.
Stop and seek help	Rapidly worsening breathlessness, difficulty speaking, chest retractions, cyanosis, faintness, or poor response to reliever medication. Follow the written asthma action plan.

7.1 Selection of practices

No single posture has been proven essential for asthma. Commonly used gentle chest-opening or spinal-mobility postures—such as supported bridge, cobra variations, fish-pose modifications, seated twists, and relaxation in a supported position—may be selected for comfort and mobility rather than because they have a unique bronchodilator action. Individualization is especially important for people with obesity, hypertension, pregnancy, osteoporosis, musculoskeletal pain, or severe asthma.

Breathing practice should emphasize comfort, smoothness, and absence of air hunger. Slow diaphragmatic or lower-rib-cage breathing may be appropriate; rapid bhasrika-like breathing, aggressive kapalabhati, and prolonged kumbhaka should not be routinely recommended to patients with asthma without expert assessment. The scientifically boring answer—gentle, gradual, repeatable practice—is often the clinically useful one.

VIII. LIMITATIONS OF THE EVIDENCE BASE

- Small sample sizes and inadequate statistical power in many trials.
- Substantial variation in yoga style, session duration, instructor training, home practice, and treatment fidelity.

- Frequent use of wait-list or usual-care controls, which cannot separate specific effects from attention and expectancy.
- Incomplete blinding, allocation concealment, adverse-event reporting, and intention-to-treat analysis.
- Greater emphasis on short-term patient-reported outcomes than on exacerbations, healthcare use, inflammation, and long-term medication requirements.
- Limited representation of severe asthma, children, older adults, and diverse health systems.
- Potential publication bias and selective reporting of positive pulmonary-function outcomes.
- These limitations do not mean that yoga is useless. The extent, specificity and durability of benefit are unclear. Studies that compare standardized yoga protocols with credible active controls; pre-register outcomes, objectively monitor adherence and report harms, or include clinically meaningful endpoints such as exacerbations, oral corticosteroid bursts, rescue-inhaler use and sustained changes in validated asthma-control scores are required.

IX. FUTURE RESEARCH PRIORITIES

1. Develop consensus-based, reproducible yoga protocols with clearly described components, intensity, progression, and instructor qualifications.
2. Recruit adequately powered multicenter samples and stratify by asthma phenotype, severity, age, obesity, anxiety, and dysfunctional breathing.
3. Use active comparator groups to distinguish yoga-specific effects from general exercise, relaxation, education, and social contact.
4. Measure validated patient-reported outcomes together with spirometry, exacerbations, rescue medication, adherence, and biomarkers.
5. Evaluate durability after supervised treatment ends and determine the minimum effective home-practice dose.

6. Conduct implementation and cost-effectiveness studies in primary care and low-resource settings.
7. Report adverse events and protocol deviations transparently.

X. CONCLUSION

Yoga therapy appears to be a reasonable and generally acceptable adjunct in selected patients with stable bronchial asthma. The most robust evidence indicates modest improvements in asthma-related quality of life, symptom perception, psychological well-being and control of breathing pattern. Objective pulmonary-function findings were inconsistent and affected by methodological shortcomings; some studies also reported nonsignificant improvements in PEFr, FEV₁, or FVC. The evidence was inadequate to infer that yoga reduces or prevents severe exacerbations, reverses airways inflammation or allows for unsupervised withdrawal of asthma medication. Thus, clinical integration ought to be evidence-concordant: gentle individualized care; open supervision; continuation of guideline-driven treatment; and explicit safe usage indicators. Yoga might help patients with asthma to live better; however, it should not be offered as an alternative to the treatments that control asthma and prevent unnecessary deaths.

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The Efficacy of Deep Belly Breathing (Adhama Pranayama) in Chronic Low Back Pain (CLBP): An Analytical Review

¹ Ms. Sandeep Kaur, ² Dr. Sakshi Nagru

¹ Research Scholar, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda

² Professor, Department of Physical Education, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India

Email Id: ¹ kaurssandeep95922@gmail.com, ² sakshinagru@gmail.com

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Abstract— Chronic low back pain (CLBP) is the primary cause of disability globally and requires biopsychosocial management instead of molecular or structural explanations and/or pharmacological intervention alone. One example is Adhama Pranayama, which is often taught as low or diaphragmatic breathing; it may also enhance rehabilitation by synchronizing respiration with trunk stabilization and by decreasing arousal due to stress. Objective: This systematic review with meta-analysis aimed to evaluate clinical and mechanistic evidence for breathing exercises in adults with chronic non-specific low back pain. Recent systematic reviews, along with evidence from small randomized trials, suggest that breathing exercises alone or in combination with core stabilization and/or multimodal exercise are associated with short-term benefits in pain, disability, respiratory function, muscle activation and selected psychosocial outcomes. It is also believed that the diaphragm plays a role in anticipatory postural control and intra-abdominal pressure; thus, there may be a mechanism by which breathing retraining can affect lumbar stability. That said, the physiological results showing increased vagally mediated heart-rate variability and potential reduced autonomic arousal with slow breathing should not be misleadingly construed as providing evidence for a particular analgesic pathway in CHRONIC LOW BACK PAIN (CLBP).

Keywords – Adhama Pranayama, chronic low back pain, diaphragmatic breathing, lumbar

stabilization, pain self-management, slow breathing.

I. INTRODUCTION

Chronic low back pain is defined as pain located approximately between the lower rib margin and the gluteal folds that continues/reappears after 12 weeks. In 2020, it was estimated that as many as 619 million people suffered from low back pain [1], and it remains the leading global cause of disability in individuals, which is expected to grow as populations and their age increase [2]. The majority of presentations in primary care are grouped as non-specific because no single pathoanatomical lesion is sufficient on its own to account for the severity, duration, or impact on function of symptoms. This shift has led contemporary management to employ a biopsychosocial model in which factors such as tissue sensitivity, motor behavior, sleep, stress, fear & expectations, physical activity (PA), work, and psychosocial context can modulate pain [3].

This broader model is crucial because chronic pain does not equate to ongoing damage to connective tissue. Individuals with CLBP can show guarded movement, lesser trunk variability, breath-holding or shallow upper-chest breathing or more bracing while executing tasks considered challenging. Although those strategies can be protective in the short-term, they tend to raise exertion levels, fatigue levels, movement fear, and pain-attention. In a case-control study, participants with chronic non-specific low back pain exhibited more altered breathing during lumbopelvic motor-control tests compared to controls [4]. Imaging studies have also demonstrated

differential diaphragm position and postural behavior amongst patients with CLBP [5]. Although these observations do not demonstrate that dysfunctional respiration causes spinal pain, they provide a plausible framework for inquiring into the use of respiratory retraining as an adjunctive rehabilitation component.

Adhama Pranayama refers to a yogic lower-breathing practice that relies on relaxing expansion of the belly and lower rib area upon inhalation, followed by an effortless exhalation which is generally slower. In present-day rehabilitation lingo, it is largely identical to diaphragmatic or belly breathing. This practice is appealing due to the absence of equipment, various positions in which it can be taught, and possibly forming part of a home workout. However, being a popular choice and physiologically plausible does not equal clinical evidence. An analytical review has to separate direct evidence in CLBP from indirect evidence from an autonomic physiology perspective, and speculative claims that have not been tested in this population.

II. REVIEW OBJECTIVES

The objectives of this review are:

- To review the clinical evidence of breathing exercises, especially diaphragmatic breathing, for chronic non-specific low back pain;
- To explain the biomechanical, motor-control, autonomic and psychological mechanisms which appear important in benefit;
- To propose a clinically pragmatic method based on Adhama Pranayama with supplemental rehabilitation;
- Identify methodological weaknesses and priorities for future studies.

Since the studies identified use different terminology and frequently insert breathing during exercise, the review does not justify that every assessed protocol is equivalent to a traditional yogic technique but assesses Adhama Pranayama as a clinically relevant form of diaphragm breathing.

III. ADHAMA PRANAYAMA: CONCEPT & PRACTICE

It is also called the lower type of yogic sectional Breathing (i.e Adhama Pranayama). On inhale, the diaphragm descends, and the abdominal wall/lower lateral ribs are allowed to expand; on exhale, it relaxes and returns without forced contraction. So, the reason you SEE this abdominal movement is related to changes in pressure and volume, NOT because we screw up and tell our belly to bear down with momentum. The shoulders and upper chest should stay fairly quiet, and the jaw, pelvic floor, and superficial abdominal muscles should not be held tight.

Involving some of the aforementioned factors that are most essential for rehabilitation, as it makes it all a little easier to replace being aware, low effort, rhythmic, and programmed into movement. A novice can practice the technique lying in a supported supine position with one hand resting on the upper chest and the other hand at the level of their abdomen. Nasal inspiration lasting roughly three to four seconds may be followed by a relaxed expiration taking two or three times the length of time; e.g., holding your breath is not required and, more importantly, may cause dizziness, anxiety, or excess bracing in sensitive individuals. Once the pattern becomes comfortable, that same strategy should be practiced in sitting, standing, and if necessary, right up to lifting prep or the initial stages of any kind of gentle mobility activity. That maximum inhalation is not the goal; rather, efficient and benign breathing and trunk control can go hand in hand.

IV. REVIEW METHODOLOGY

Because of the variation in interventions (types, dosages, comparisons), we used a narrative analytic approach. We reviewed peer-reviewed clinical trials, systematic reviews, meta-analyses, biomechanical studies, and authoritative clinical guidance. Methods: Web searches were performed,

limiting the data to available articles published before October 2023 using search terms such as chronic low back pain, diaphragmatic breathing, breathing exercise, pranayama, respiratory muscle training, diaphragm muscular stabilization of a major component in the region with written stability diuretic change between abdominal cavity and thoracic experience of quantitative measure or-sensitivity Heart-rate variability (HRV), disability and fear avoidance. Adult studies of chronic non-specific low back pain were prioritized, as were mechanistic studies with direct relevance to postural and autonomic regulation.

Evidence was graded by study design, sample size, the use of breathing alone or with additional treatment, presence of an active control and clinical relevance of outcomes. As this is an analytical, but not a formally registered systematic review, it makes no claim about exhaustive retrieval upon which a PRISMA-based risk-of-bias assessment would be based. All conclusions should be viewed cautiously and updated when bigger trials are published.

V. EVIDENCE SYNTHESIS

A. Pain and Functional Disability

Earlier appraisal of the literature concluded that moderate, Grade B evidence supported including breathing exercises in the care of chronic non-specific low back pain, while emphasizing the small number of eligible studies and the need to integrate patient preference and clinical judgment [8]. An earlier randomized breath-therapy trial also reported clinically relevant improvement, although its intervention was broader than Adhama Pranayama alone [20]. Subsequent trials have strengthened, but not settled, the case. Finta et al. randomized individuals with chronic low back pain to a complex exercise program with or without additional diaphragm training. Pain improved in both groups, while the diaphragm-training group demonstrated changes in diaphragm thickness and selected lumbar stabilizer muscles, including transversus abdominis and multifidus [9]. These findings suggest a training

effect on the deep trunk system, but they do not establish that diaphragm training alone was responsible for pain relief.

Masroor et al. compared core stabilization alone with core stabilization plus diaphragmatic breathing in 22 participants over 12 sessions. Both time-related improvement and selected interaction effects were reported for pain, disability, fear-avoidance beliefs, sleep quality, muscle activity, and chest expansion. However, between-group superiority was not uniform across all outcomes [10]. This nuance is clinically important: adding breathing may improve how an exercise program is performed or tolerated, even when it does not produce a large independent effect on every measure.

Recent meta-analytic evidence is encouraging. Jiang et al. Findings included pooled reductions in pain and Oswestry Disability Index scores, with standardized mean differences of nearly -0.84 (pain) and -0.74 (disability) [11]. An additional systematic review reached a similar conclusion in which breathing exercises may provide relief for low back pain but caution against certainty due to methodological quality and inconsistent protocol [12]. Pooled effects can be compelling, but combine interventions that range from diaphragmatic breathing and respiratory muscle training to yoga-based or multimodal programs [18]. The safest conclusion is that breathing exercises can provide short-term improvement in symptoms and function, particularly as an adjunct; however, data from large trials do not yet support efficacy of Adhama Pranayama as a stand-alone intervention.

B. Respiratory Function and Trunk Motor Control

The diaphragm plays a dual role, one pertaining to respiration and the other contributing towards posture. Electrophysiological studies in healthy adults showed anticipatory diaphragm activation prior to quick limb movement, suggesting its involvement in postural stabilization [6]. Co-activation of the diaphragm with associated abdominal muscles maintains intra-abdominal

pressure for prolonged periods during postural tasks [7]. These mechanisms help explain why a variety of systems cannot be fully separate from each other (such as respiration and trunk control).

Patients with CLBP may also show modified coordination rather than simple muscle weakness. Roussel et al. detected disrupted respiration during motor disruption tests [4], and Kolar et al. showed alterations in postural function and diaphragm position [5]. In addition, inspiratory muscle training has been related to changes in proprioceptive utilization with reduced low back pain [19]. These studies collectively suggest a model in which breathing retraining is used to decrease unnecessary breath-holding, improve management of intrathoracic pressure, and allow for more flexible activation of the diaphragm, abdominal wall, pelvic floor, and spinal extensors. They don't buy into the simplistic assertion that, with every patient, the diaphragm is "weak," or that abdominal expansion suddenly braces up and stabilizes their spine.

C. Autonomic Regulation, Stress, and Pain Perception

Slow voluntary breathing reliably influences cardiovascular autonomic markers. A systematic review and meta-analysis found that slow breathing increases vagally mediated heart-rate variability during practice and can produce post-practice effects [13]. A broader review described associated changes in respiratory sinus arrhythmia, baroreflex function, central nervous system activity, and psychological state [14]. These findings provide a plausible pathway through which paced breathing may reduce arousal, muscle guarding, and distress during painful movement.

However, heart-rate variability is not a direct pain meter, and increased vagal indices do not prove that pain has been biologically "switched off." In CLBP, autonomic change is more appropriately viewed as one component of a broader self-regulation process. Slower breathing can shift attention from threat to controllable bodily sensation, reduce urgency, and

create a predictable rhythm during movement. These effects may reduce pain amplification and improve willingness to move, but direct mediation studies in Adhama Pranayama are lacking.

D. Fear Avoidance, Sleep, and Self-Management

Concerns over pain may encourage activity avoidance, deconditioning, and disability. According to the fear-avoidance model, behavior is regulated not just by pain intensity but also by threat perception and catastrophizing [15]. Breathing practice might act as a graded exposure facilitator: the patient learns to stay relaxed, maintain breathing and do a movement that was previously protected. We see such an interpretation as compatible with evidence connecting pain, motor behavior and physical activity [16]. This also corresponds with the positive changes in selected fear-avoidance and sleep outcomes previously observed when combining diaphragmatic breathing with core exercise [10].

The technique might be as much a self-management value as it is of physiological consequence. Patients are trained in a simple breathing routine that they can use during flare-ups, before exercise, or when stress spikes. This can enhance feelings of control and motivation. Even so, the technique should not be framed as an immediate, necessary pain-elimination technique. The problem with offering such a promise is that it can place another demand for performance, further promoting the notion that you should not move unless symptoms go away.

VI. PROPOSED MECHANISMS OF ACTION

A. Diaphragm, Pressure Regulation, and Spinal Support

When the diaphragm descends with inspiration it causes changes in abdominal pressures as well as interacts with both the abdominal wall and pelvic floor. When tasks are time-on-target, this system can augment trunk stiffness independent of a maximal contraction in superficial muscle. The support that

results is sometimes called an internal brace, but the analogy should be applied with caution. Healthy stabilization is not static: intraabdominal pressure and muscular activity vary with phase of breathing, load, speed, posture, and individual anatomy. Bracing too much or trying hard, in a Valsalva-like manner, may cause fatigue and decrease movement variability. Adhama Pranayama is implicated in that it enables the individual to learn low-load pressure modulation prior to performing higher load activities.

B. Restoration of Respiratory-Motor Coordination

Pain may affect the timing or distribution of muscle activity. Thus, some patients hold their breath when they bend, lift, or move a limb because that strategy increases stiffness in the short term. Without this option for exploring new movement patterns, hyper-responsiveness is ingrained in continuous breathing (though retraining continuous breathing can mitigate this rigid response; see Bulletproofing Breathing). We can infer that you are not strengthening one single muscle; instead, coordination between them may improve. It is this difference that clarifies why breathing exercises are naturally combined with progressive strengthening, walking, mobility, and task-specific practice.

C. Autonomic and Affective Modulation

An extended comfortable expiration and low-frequency breathing can enhance cardiorespiratory oscillation and vagally mediated variability [13]. This may feel subjectively as calmness, less urgency, and better focus. As I discussed in the lower arousal section, lower arousal in a pain context decreases protective co-contraction and makes it easier to expose to movement. Allegations suggesting that slowly breathing directly elevates gamma-aminobutyric acid, inhibits specific inflammatory cytokines or permanently restores the pain system in CLBP are needlessly underexploited and should not be described as settled clinical truths.

D. Attention, Expectation, and Self-Efficacy

Breathing practice is a form of structured interceptive attention. If the teaching is supportive and not catastrophic, then the patient can have bodily sensations without regard to any perceived threat of harm. Repeats likely foster self-efficacy: they transform discomfort into something to be experienced and worked through as the movement persists. Rather, it simply realizes and appreciates that pain is an experience we build for ourselves; one generated by context, focus, feelings, and what we learn about the world.

VII. CLINICAL INTEGRATION & SAFETY

International guidelines for management of chronic primary low back pain recommend person-centered, non-surgical care including education, exercise (structured exercises and active interventions), psychological interventions if indicated, and self-management support [17]. In accordance with this scheme, Adhama Pranayama (control of the respiratory system) applies as an adjunct and not a replacement for active rehabilitation methods. Gradual initiation is one method to prevent this:

- Start at Supine/Supported/Hurdle position. Place one hand on the upper chest and the other over the lower ribs or abdomen. Soft nasal sniff feeling with deep stomach breathing and expansion
- Give a peaceful rhythm by breathing slower yourself (inhaling for three to four seconds, exhaling for four to six seconds) for around five minutes. The timing is a matter of comfort; depth need not be forced.
- You do it once or twice a day and immediately prior to performing the exercise reps that typically elicit guarding. It is only when the patient is able to breathe without bringing his shoulders up, pain or dizziness will it go into sitting and then standing.
- Movement with Breath as Service distributed device level of plan-assisted movement. Inhale

and exhale WITH effort also happens with sit-to-stand, bridging, or lifting practice and is continuous for mobility and endurance work.

- Assess pain severity, disability or dysfunction, and compliance before treatment and at various intervals after completed care. Heart-rate variability can be used for research, but one does not need it to provide usual care quality.

In general, breathing exercises come with relatively low risk of causing direct harm, but they have to be discontinued if simple dizziness, faintness (a feeling of unsteadiness), chest pain, significant shortness of breath, panic, or neurological signs appear. In the case of an introductory CLBP protocol, prolonged retention and aggressive hyperventilation are avoided. Patients with unexplained weight loss, fever, major trauma, progressive weakness or saddle anesthesia (or bladder/bowel disturbance) or some other "red flag" need to be followed by a physician rather than treated alone. At the same time, pregnancy, moderate to severe respiratory or cardiac illness, recent abdominal surgery, and Axis 1 diagnosis of severe anxiety associated with breath-focused practices should also be individualized [5].

VIII. LIMITATIONS & RESEARCH GAPS

The limitations of the literature are many and recurring. One reason for this is that small and underpowered trials give unstable effect estimates. Second, there are heterogeneous methods included in "breathing exercise": diaphragmatic breathing (DB), resisted inspiration (RI) [3], yoga breathing, paced breathing, breath awareness, and breathing embedded in complex exercise (BCE). Third, co-interventions make attribution difficult. When both groups receive core stabilization, and one group receives breathing, neither group should worsen; the important question is whether there is an incremental benefit, and that has not been entirely consistent [10]. Fourth, masking of participant and therapist is seldom achievable, which strengthens

expectation and focus effects. Fifth, durability and prevention of relapse are still uncertain because follow-up is frequently short.

Well-powered multicenter randomized designs, utilizing preregistration and active attention controls as well as clearly described breathing dose with competency checks, adverse-event reporting, and follow-up periods of six to twelve months should be the goal of future studies. Studies should differentiate Adhama Pranayama from other breathing practices and evaluate both independent and adjunctive delivery. Core outcomes should include pain, ODI or Roland-Morris disability, patient-specific function, physical activity, sleep, fear avoidance, and QoL (treatment adherence). Mechanistic analyses can investigate whether changes in diaphragm function, motor coordination, heart-rate variability, or self-efficacy statistically mediate clinical improvement. Such subgroup research is also required as patients defined by hypersensitivity to breath-holding, heightened arousal, respiratory dysfunction or fear of movement may differ in their response from patients whose disability is predominantly determined by other factors.

IX. CONCLUSION

Adhama Pranayama is a feasible and well-reasoned breathing intervention that provides adjunct rehabilitation for chronic non-specific low back pain. The best evidence also indicates breathing belongs to a multimodal program, not that it appears as an isolated cure. Thus, small randomized trials and pooled analyses show potential short-term improvements in pain, disability, respiratory function, deep trunk muscle behavior, fear avoidance and sleep, while mechanistic research establishes the participation of the diaphragm in posture control and pressure regulation. Changes in autonomic markers underlie some of the motor effects during slow breathing, but it is unclear whether these changes directly contribute to analgesia.

Gentle diaphragmatic breathing therefore might contribute to reductions in breath-holding, improvements in self-management, and be accompanied by graded movement using patient education and physical activity according to individual tolerance. The scientific verdict would be cautiously positive: Adhama Pranayama appears to work, costs nothing, and has a low likelihood of adverse effects for many patients, but definitive tests of an independent effect will probably require high-quality long-term studies.

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AI-Based Recognition and Analysis of Gatka Martial Arts Techniques Using Human Pose Estimation and Machine Learning

¹ Ms. Prabhjyot Kaur, ² Ms. Anija Mittal

¹ Student, Department of Computer Applications, Guru Kashi University, Bathinda, India

² Assistant Professor, Department of Computer Applications, Guru Kashi University, Bathinda, India

Email Id: ¹ prabhjyotkour9@gmail.com, ² anijamittal@gmail.com

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Abstract— Gatka is a traditional Sikh martial art, which is defined by synchronized movement of the body, the weapons, the defensive actions and the quick transitions. Teaching and evaluation are mostly based on the expertise of teachers and the process of observation, making it hard to quantify, provide quick feedback, and systematically preserve in digital format. This paper proposes a framework called AI-GATKA which utilizes machine learning and human pose estimation to achieve the aim of recognizing and analysing basic Gatka techniques. Media Pipe Pose processes video frames to extract body landmarks such as shoulder, elbow, wrist, hip, knee and ankle positions. Landmark points are transformed to posture, joint-angle, alignment and temporal-motion features. A Support Vector Machine (SVM), Random Forest and Neural Network classifiers are then employed to determine five technique categories: basic stance, forward strike, defensive block, side movement, and circular movement. The data set used in the prototype configuration reported in the source study consists of 250 samples, with 80% of the data used for training and 20% of the data used for testing. The SVM achieved 86%, the Random Forest 91% and the Neural Network 94% accuracy in the classification. This framework shows how the use of artificial intelligence with poses can help with technique recognition, training, objective assessments and digital preservation of Gatka. The paper also outlines the main drawbacks of camera viewpoint, lighting, among practitioners, occlusion, and fast movements of weapons. Main keywords—

Artificial Intelligence, Computer vision, Gatka recognition, Human action recognition, Machine Learning, MediaPipe Pose, Pose-based Analysis.

Keywords – *artificial intelligence, computer vision, Gatka recognition, human action recognition, machine learning, MediaPipe Pose, pose-based analysis.*

I. INTRODUCTION

Martial arts have a deep history of transmission of Knowledge and embodied Practice. They develop their self-defence skills and their physical conditioning, discipline, concentration, coordination, timing and control of their decision making. Digital documentation may be used in addition to oral, instructor-led, and teacher-student transmission to ensure that movements can be reproduced, and measurable descriptions of the way technique is executed.

In recent years, the automatic interpretation of human motion has significantly improved thanks to the advances in artificial intelligence, computer vision and deep learning. This is a description of the fast developments in pose estimation, both two-dimensional and three-dimensional, in the fields of keypoint detection, tracking and action recognition [1, 3, 4]. MediaPipe offers a highly effective perception-pipeline architecture, which is also capable of extracting landmarks from regular RGB video in real time [2]. These have allowed pose-based applications, such as fitness, sports activity classification, healthcare, rehabilitation and human-computer interaction [5]-[6] [21]-[22] [27].

The Gatka technique is a unique recognition problem as it incorporates body position, movements with the feet, rotations and weapon lines. Landmark estimates can be degraded by self-occlusion, clothing, motion blur, background activity and overlap of the body with the weapon, and there can be variability in the technique across practitioners. Martial arts that are not traditional weapons are not well covered in existing datasets that focus on action-recognition in daily life, fitness exercises, and popular sports. Therefore, a special technique-level framework and data set is needed for the Gatka analysis.

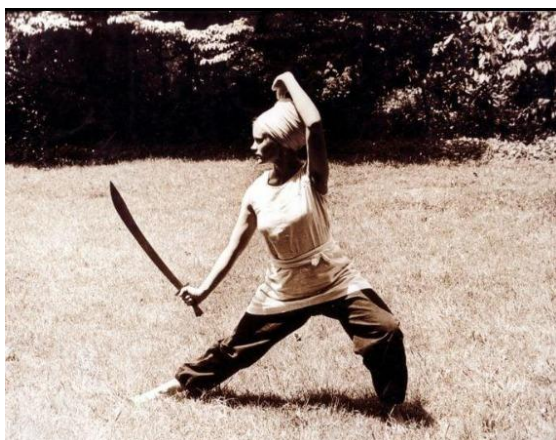


Fig. 1. Example Gatka posture illustrating coordinated stance and weapon handling.

This research aims to present an AI-GATKA framework to extract the pose landmarks, movement features and machine readable labels of the technique of Gatka from the videos. The contribution is threefold: (1) it provides a pose-centred pipeline of the five basic Gatka techniques; (2) it puts forward a comparison between conventional and neural classification models, based on the reported prototype data; and (3) it enumerates applications for training support, objective assessment, and cultural preservation.

II. BACKGROUND & RESEARCH MOTIVATION

A. Gatka Martial Art

Gatka is a martial art tradition of the Sikhs that combines the use of weapons, Defensive and Response, Footwork, Body Alignment, Timing and

Tactical Positioning. The upper and lower arm/legs and the weapon must work continuously together to perform well. Many of the details, such as the orientation of the joints, stance width, balance, hand path or timing of movement can vary slightly and affect the quality and safety of a technique.

- **Weapon handling:** Movement of traditional weapons in a controlled manner, in the correct direction, speed, accuracy and safety.
- **Defensive movement:** Defensively moving patterns in response to an incoming action such as blocking and avoidance patterns, and counter-movement patterns.
- **Footwork:** Effective and stable repositioning, maintaining balance and attacking and defending.
- **Posture and coordination:** Coordination and alignment of the trunk, arms, legs and weapon throughout a technique.
- **Combat transition:** Transition from stance, attack, defense and recovery at various distances and times.



Fig. 2. Gatka practitioners performing weapon-based movement sequences.

B. Research Motivation

Use of traditional evaluation is helpful because it is based on the knowledge of context, intention, and safety, as well as stylistic variation, that is gained by the instructor's years of experience. However, manual observation is not easily standardized, scaled and archived. A computer assisted system can provide consistent body geometry and timing of

movement measurements, and can still leave the instructor at the conclusion as the final decision maker. AI-GATKA is thus not a replacement, but rather an assistant that improves teaching, based on measurable evidence, a longitudinal record and consistent preliminary feedback.

The research is motivated by four needs: digital preservation of technique examples; automated extraction of movement descriptors; objective comparison of learner and reference performances; and accessible training support when expert supervision is not continuously available. Several pose-based systems have been explored to correct exercise [7] – [14], to screen the biomechanics of an exercise [17] – [20] and to analyze injury risk [23] – [27] and sports performance [28]. The above developments suggest that a system designed accordingly can be modified to meet the demands of structural and cultural needs of Gatka.

III. RELATED WORK

Zheng et al. reviewed deep-learning methods for human pose estimation and provided an overview of the current development of keypoint detection, multi-person tracking and benchmark test [1]. MediaPipe is a framework of reusable components to build real-time perception pipelines on diverse platforms introduced by Lugaresi et al. [2]. Song et al. surveyed the relationship of pose estimation and action recognition, pose representations and temporal modelling strategies [3]. Zhou et al. also investigated deep models utilizing convolutional networks, graph neural networks, and Transformers in the areas of pose estimation, tracking, and action recognition [4].

In the domain of fitness and sports, pose-estimation (for exercise) and action-recognition techniques for exercise movements were proposed by Fu et al. [5] and Sport PoseNet used MediaPipe landmarks and a deep image model, achieving 92.67% validation accuracy on a custom multi-sport dataset, respectively [6]. A series of related studies have focused on the assessment of squat, which can be

interpreted, temporal models for prediction of injuries, tracking of the skeleton, lower-limb movements, and correction of the movement [7]-[14]. There are various sport-specific applications such as pose-based tackle detection, skiing analysis, running joint-angle assessment, landing-error scoring and athlete tracking [15]-[20]. Real-time systems for pose tracking and skeletal analysis, as well as graph-based analysis of the skeletons and biomechanical study of different seasons, show that the trend towards data-driven sports coaching is ongoing [21]-[27].

However, this development does not seem to have been reflected in the existing literature, which is still lacking of a special Gatka dataset or a technique-recognition pipeline that specifically considers weapon-based movement. The majority of systems rate general activities or isolate exercises. This leaves a gap in the research to be filled with culturally specific data collection, handling of the rapid movements of the weapons, technique-level labelling and feedback appropriate to a traditional martial-art learning context.

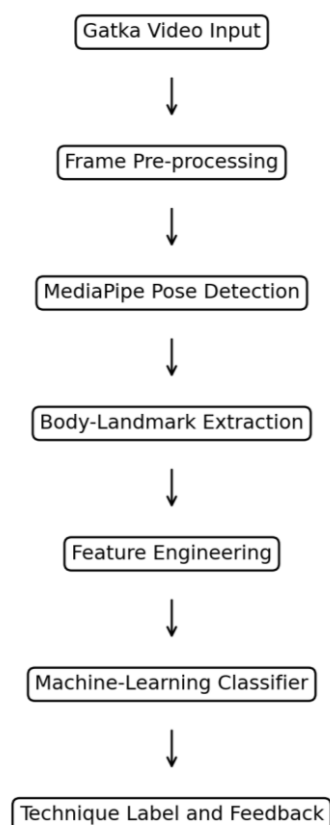
TABLE I
SUMMARY OF REPRESENTATIVE POSE-BASED STUDIE

Ref.	Data/Domain	Core Method	Reported Outcome or Gap
[1]	Pose benchmarks	Deep pose-estimation survey	Broad taxonomy; no Gatka-specific dataset
[2]	RGB perception pipelines	MediaPipe framework	Real-time modular processing; general-purpose
[3], [4]	Pose/action datasets	CNN, GNN, Transformer methods	Strong general action coverage; limited traditional martial arts
[5]	Fitness movements	Pose estimation and action recognition	Sports-oriented recognition; no weapon-based analysis
[6]	1,010 sports images	MediaPipe + ResNet-200	92.67% validation accuracy; common sports only
[7]-[14]	Exercise and biomechanics	Pose, temporal and biomechanical models	Demonstrates correction and risk-assessment potential

Ref.	Data/Domain	Core Method	Reported Outcome or Gap
[15]- [27]	Sport-specific motion	ML, deep learning and skeletal tracking	Supports coaching applications but not Gatka technique labels

IV. PROPOSED AI-GATKA FRAMEWORK

The pipeline proposed in this work consists of a series of stages including frame preparation, pose detection, feature extraction and classification of the technique. Design is based on the concept of pose coordinates, rather than on raw image pixels. This lowers the dimensionality of the input, simplifies the features to be more interpretable and enables the system to focus on the practitioner's geometry, and not on irrelevant visual background information.



A. Data Collection

Video is taken of Gatka practitioners doing the basic movements with the help of video cameras in a controlled and varied environment. The proposed categories are: basic stance, forward strike, defense block, side move and circular move. Videos will

feature different heights of practitioners, clothing, tempo of movement, distance of camera and different styles of executing the movement. Technical validity of the labels should be assigned or confirmed by qualified Gatka instructors.

B. Human Pose Detection

First, each video is divided into frames and then each frame is processed using Media Pipe Pose [2]. There are 33 landmarks identified by the model, with some landmarks being of particular interest for stance, arm trajectory, trunk orientation, and foot placement: shoulders, elbows, wrists, hips, knees, and ankles. For each landmark a horizontal coordinate and a vertical coordinate is stored, as well as a depth coordinate and visibility and/or confidence information.

C. Feature Extraction

The significant stream becomes numerical attributes of the stream. The position features include normalized elbow and shoulder locations, hip and knee alignments, and trunk inclination and bilateral symmetry; the angle features include elbow, shoulder, hip and knee positions; the alignment features include trunk inclination and bilateral symmetry; and the temporal features include velocity, acceleration, direction change and frame to frame displacement. Normalization with respect to hip centre or shoulder width, or body height, decreases the sensitivity to the distance between the camera and the participant or the size of the participant.

D. Technique Classification

The extracted feature vectors are then given to the supervised classifiers. On moderate dimensional features a Support Vector Machine (SVM) would be a good baseline, Random Forest would provide non-linear decision boundaries and feature-importance estimates, and a Neural Network (NN) could learn more complex relationships between posture and motion descriptors. Model selection should be done based on the cross-validated accuracy, precision,

recall, F1-score, latency and robustness, and not accuracy alone.

V. METHODOLOGY

A. Dataset and Pre-processing

The prototype data set reported is 50 samples per 5 techniques of Gatka which makes a total of 250 samples. The data set is split into 80% training data and 20% testing data. The videos are cleaned of corrupted or irrelevant frames and frames are standardized prior to landmark extraction. Ideally, the split between train and test sets should be "practitioner independent", meaning that a particular practitioner should not be in both sets: otherwise, the accuracy measured may not reflect technique recognition for general practitioners, but rather for that practitioner.

TABLE II
PROPOSED TECHNIQUE CLASSES

Technique	Operational Description
Basic stance	Ready posture before an offensive or defensive action
Forward strike	Weapon movement directed toward the opponent
Defensive block	Protective action intended to intercept or redirect an attack
Side movement	Lateral repositioning while preserving balance and readiness
Circular movement	Rotational movement coordinated with weapon handling

B. Landmark and Angle Representation

The landmark vector for landmark i at frame t is $P_{i,t} = (x_i, y_i, z_i, v_i)$ and v_i is the landmark's visibility. The cosine of the angle at B , between the vectors BA and BC , is calculated, and this angle is used to determine the angle at B , between $A-B-C$. Time derivatives of landmarks or angles are used to get velocity and acceleration descriptors. Low confidence landmark points can be interpolated, smoothed or omitted based on a quality criterion.

C. Model Training and Evaluation

Feature scaling process is used if needed, primarily for training SVM and Neural Networks. The hyperparameters should be determined by cross validating on the training set. Final model is tested on the test set that was not used in the training process. Apart from overall accuracy, a confusion matrix and class-wise precision, recall and F1-score are recommended as similar techniques might be misinterpreted even if the overall accuracy is high.

VI. EXPERIMENTAL SETUP

The proposed implementation is based on Python, OpenCV, MediaPipe Pose, NumPy and Pandas, and scikit-learn which are employed for frame processing, extracting landmarks, preparing the features, and implementing the conventional machine-learning models. Prototype development can be done on a standard desktop or laptop computer, with a minimum of an Intel Core i5 processor, 8 GB of RAM, and an HD camera. The performance of the deployment in real time is dependent on resolution, frame rate, complexity of the model and hardware acceleration.

TABLE III
SOFTWARE & HARDWARE CONFIGURATION

Component	Specification
Programming language	Python
Computer vision	OpenCV
Pose estimation	MediaPipe Pose
Machine learning	Scikit-learn
Data processing	NumPy and Pandas
Processor	Intel Core i5 or higher
Memory	Minimum 8 GB RAM
Camera	HD webcam or equivalent
Operating system	Windows 10/11 or Linux

VII. RESULTS & DISCUSSION

According to the source manuscript the Support Vector Machine, Random Forest and Neural

Network had prototype accuracy of 86%, 91% and 94%. The Neural Network is thus the most accurate of the three, with the reported accuracy of 78.3% compared to 75.3% for Random Forest and 70.3% for SVM. The pattern is consistent as a neural model can accommodate the non-linear relationships between a number of joint and motion features. The accuracy values reported however should be considered in conjunction with the sampling protocol, class balance, independence of the participants and the lack of class-wise metrics.

TABLE IV
REPORTED MODEL ACCURACY

Model	Accuracy
Support Vector Machine	86%
Random Forest	91%
Neural Network	94%

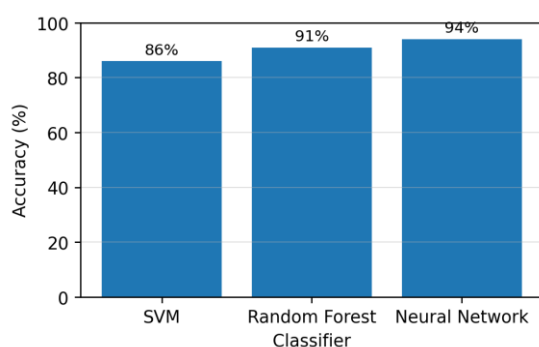


Fig. 4. Reported classification accuracy of the three models.

There are several things which can decrease the quality of the recognition. Body-only pose models may not be a direct representation of fast-moving weapons. Wrists, elbows or lower-limb landmarks could be obscured by extreme camera angles and/or self-occlusion. Landmark confidence may be decreased with lighting and background variation. Lastly, the practitioner can perform the same technique by a valid style of variation. Practitioner-independent testing, landmark-confidence filtering, temporal sequence modelling and integration of weapon detection/tracking are motivators for these issues.

VIII. APPLICATIONS

The proposed framework is able to facilitate interactive training by comparing the movement of learners with examples validated by instructors and give a general idea of the deviation in the stance, alignment and timing of the movement of the learner. It can help teachers to create uniform initial measurements and session histories. Video and landmark repository could also aid in Digital Preservation of Gatka techniques. Further validation could be expanded to mobile coaching, remote practice review, competition analysis and Augmented/Virtual reality learning environments.

IX. LIMITATIONS & FUTURE WORK

Some of the main drawbacks of the prototype are the small size and balanced nature of the dataset, the lack of evidence of practitioner diversity, possible data leakage if performers are present in both the training set and the test set, and the lack of detailed precision, recall, F1-score and confusion-matrix results. The body landmarks provided by MediaPipe are not a direct model of the weapons, but they are used to estimate them. The estimation of the body landmarks is crucial for Gatka. The need for real-time feedback, culturally relevant technique annotations and quality scoring by the instructor also needs further development.

Future research needs to create a large multi-view, expert-annotated dataset for Gatka, assess practitioner-independent and cross-environment generalization, integrate weapon detection and tracking of the trajectory, compare recurrent, temporal-convolutional, graph-based and Transformer models, quantify the latency on mobile hardware, and undertake usability studies with learners and teachers. Feedback should be able to be explained, and should not be presented as algorithmic output (or even "automatic feedback") instead of expert feedback.

X. CONCLUSION

We have developed a framework using AI to recognize and analyse basic Gatka technique using Media Pipe Pose and machine-learning classification. The framework converts a video into body landmarks, posture and motion feature and technique prediction. The results of the prototype experiments in the report indicate that the Neural Network outperforms Random Forest and SVM, and indicate that these techniques should be tested with more robust validation, using more diverse data, and with weapon-aware modelling. The fusion of traditional Gatka knowledge with pose-based AI provides a stepping stone towards technology-assisted training, precise movement analysis, and responsible digital preservation.

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A Review on Chilli Disease Detection Using Deep Learning

¹ Ms. Arvinder Kaur, ² Mr. Sukhpreet Singh

¹ Student, Department of Computer Applications, Guru Kashi University, Bathinda, India

² Assistant Professor, Department of Computer Applications, Guru Kashi University, Bathinda, India

Email Id: ¹ arvindergharu3@gmail.com, ² sukhpreetsingh@gku.ac.in

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Abstract— Agriculture is one of the most important sectors in the world, especially in India, where a large proportion of the population depends on farming for their livelihood. Chilli (*Capsicum annum*) is one of the crops that is widely cultivated with extensive application in food, medicine and spices. But chilli plants are often struck by disease conditions like Chilli Leaf Curl, Bacterial Leaf Spot, Powdery Mildew, Mosaic Virus and Anthracnose which is detrimental to crop quality and yield, resulting in significant economic losses for the farmers. In the past farmers or agricultural specialists would do the identification of the disease manually, which is a time consuming, expensive and error prone task, especially in large farming regions. In the era of Artificial Intelligence (AI) and Deep Learning (DL), smart agriculture systems that can automatically identify diseases by analyzing leaf images have become more practical. While describing the different deep learning models, this paper reviews and compares their accuracy, precision, recall, and computational efficiency for chilli disease detection, which include Convolutional Neural Networks (CNN), YOLO, ResNet, MobileNet and Vision Transformers (ViT). Additionally, the impact of image preprocessing, feature extraction, and data augmentation on enhancing accuracy is highlighted, as are several challenges like small datasets, environmental variation, and computational expenses. Finally, the paper presents the future research directions such as IoT based monitoring, drone based imaging and explainable AI for sustainable precision farming.

Keywords – Smart Agriculture, Chilli Disease Detection, Deep Learning, Convolutional Neural

Network, Image Processing, Artificial Intelligence, Precision Farming.

I. INTRODUCTION

In India, agriculture is a major livelihood of a significant part of the population and also a leading economic activity in the country in terms of its contribution to the food security and economic development of the world [1]. Chilli is one of the most important spice and vegetable crops which is utilized in the cooking, food processing, pharmaceutical and natural dye industry [2]. Although chilli is an important crop, it is highly susceptible to various fungal, bacterial and viral diseases which are capable of causing substantial losses in quality and quantity of chilli yield [3]. Some of the most common diseases observed in chilli plants include the following:

- Leaf Curl Disease
- Bacterial Leaf Spot
- Mosaic Virus
- Powdery Mildew
- Anthracnose

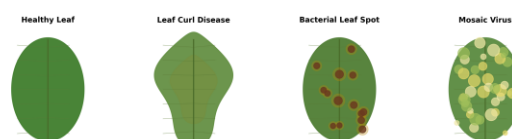


Fig. 1. Schematic comparison of a healthy chilli leaf against common disease symptoms: leaf curl, bacterial leaf spot, and mosaic virus.

Farmers typically rely on visual inspection of leaves or consultation with agricultural extension officers to diagnose these conditions [4]. However, manual identification is inherently subjective, time-intensive, and often unreliable, since several diseases exhibit overlapping visual symptoms in

their early stages [5]. Furthermore, continuous monitoring of large cultivated areas is logistically difficult, delaying intervention and increasing crop losses [6].

Unlike traditional machine learning methods that require handcrafting discriminative features, deep learning models can automatically learn features such as color variation, leaf texture, and lesion patterns from images [7], [8]. The ability to detect disease in the early stages using such systems, gives farmers the ability to apply appropriate and targeted interventions at the right time, reducing damage to the crop and unnecessary pesticide usage [9].

Smart agriculture systems combine various complementary technologies to enable powerful, scalable disease monitoring, such as:

- Artificial Intelligence (AI)
- Internet of Things (IoT)
- Deep Learning (DL)
- Image Processing
- Cloud Computing

These technologies combined will facilitate better monitoring of crops at real-time, minimize manual checking and improve sustainable and productive farming [10]. This paper provides a comparative analysis of the state-of-the-art deep learning architectures used for chilli disease detection and outlines the challenges and future prospects of chilli disease detection. Smart agriculture pipeline which supports such systems is discussed.

II. DEEP LEARNING IN SMART AGRICULTURE

Deep learning is a sub area of machine learning that uses multi layered artificial neural networks to learn hierarchical representations automatically from raw data [11]. Deep learning has been applied successfully in agriculture to a number of tasks, such as:

- Detecting plant diseases
- Identifying pests
- Monitoring crop health

- Predicting crop yield

The pictures taken for training the models are typically taken by a smartphone camera, unmanned aerial vehicles (drones), or stationary cameras equipped with IoT capabilities across the field [12]. Most smart agriculture disease-detection systems have a general processing pipeline that includes five general stages: image acquisition, preprocessing, feature extraction, classification, and result prediction [13] as shown in Fig. 1.

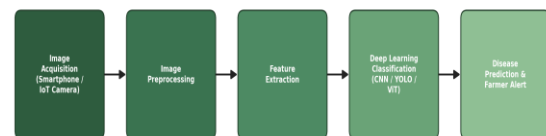


Fig. 2. General deep learning workflow for smart agriculture-based chilli disease detection.

In pre-processing, operations like resizing, noise removal, contrast enhancement, etc. are performed to normalize the input images and minimize the effect of lighting and background variation [14]. Data augmentation is often employed to artificially generate more training data, and is known to boost model's generalization ability when the training set is small [15] and involves the following: Rotation, Flipping, Scaling, Color Jittering. After the preprocessing, convolutional or attention based layers are employed to select relevant visual features and then are sent to a classification head, that identifies the disease class [16].

III. DEEP LEARNING MODELS FOR DISEASE DETECTION

A. Convolutional Neural Network (CNN)

CNN is one of the most popular deep learning architectures used in image classification problem in agriculture [11] till today. Its multi-layered architecture consisting convolutional, pooling and fully connected layers allows for the automatic extraction of low-level and high-level visual features directly from chilli leaf images [17] like edges, texture, and color patterns.

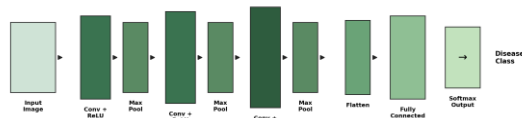


Fig. 3. Typical convolutional neural network architecture used for chilli leaf disease classification.

Advantages: High classification accuracy, automatic feature extraction, and strong effectiveness on image-based datasets [11].

Limitations: Requires large labeled datasets and substantial computational resources for training [18].

B. YOLO (You Only Look Once)

YOLO is a single-stage object detection algorithm that can detect and localize multiple disease symptoms in a single leaf or canopy image [19]. It is especially interesting for use in monitoring systems that can be deployed in the field, because of its ability to make inferences in real time [14].

Benefits: High precision, real time and fast detection speed in multi-object situations [19].

Limitations: Relatively complex network structure and reliance on GPU acceleration to achieve real-time throughput [20].

C. ResNet (Residual Network)

ResNet introduces residual (skip) connections that mitigate the vanishing gradient problem, allowing much deeper networks to be trained effectively [16]. This architecture has demonstrated strong performance on large, complex agricultural image datasets [21].

Advantages: Improved classification accuracy and robust performance on large-scale datasets [16].

Limitations: High computational cost due to network depth [21].

D. MobileNet

MobileNet is a lightweight CNN variant that uses depth-wise separable convolutions to drastically reduce the number of parameters, making it well suited for deployment on mobile devices and resource-constrained IoT hardware [18].

Advantages: Low memory footprint and suitability for embedded and IoT-based deployment [18].

Limitations: Slightly reduced accuracy compared to larger, deeper networks [22].

E. Vision Transformer (ViT)

Vision Transformers depart from convolution-based processing entirely, instead applying self-attention mechanisms to image patches to capture long-range spatial dependencies [20]. Recent studies report that ViT-based models achieve superior performance on plant disease classification benchmarks when sufficient training data is available [23].

Advantages: Excellent overall performance and stronger global feature understanding compared to purely convolutional models [20].

Limitations: Requires large training datasets and incurs high training cost [23].

IV. CHALLENGES IN CHILLI DISEASE DETECTION

Although deep learning approaches have achieved promising results, several practical challenges continue to limit their widespread adoption in real-world farming environments.

A. Limited Datasets

Publicly available agricultural image datasets often contain a limited number of labeled samples per disease class, which constrains model generalization and increases the risk of overfitting [24].

B. Environmental Conditions

Variations in lighting, shadow, background clutter, and camera angle can substantially degrade image quality and reduce model reliability under field conditions [25].

Similar Disease Symptoms

TABLE I
COMPARATIVE ANALYSIS OF DEEP
LEARNING MODELS

Algorithm	Accuracy (%)	Precision	Recall	F1-Score
CNN [11]	92.5	0.91	0.90	0.90

Algorithm	Accuracy (%)	Precision	Recall	F1-Score
YOLOv5 [14]	95.3	0.94	0.93	0.93
ResNet50 [16]	94.1	0.93	0.92	0.92
MobileNet [18]	90.4	0.89	0.88	0.88
Vision Transformer [20]	96.2	0.95	0.95	0.95

But this increase in accuracy comes at the cost of increased computing power and computational accuracy–efficiency trade-off needs to be considered when choosing models for field deployment [19], [20]. The representative training and validation accuracy and loss curves for a baseline CNN model are shown in Fig. 4 for 30 epochs of training, and representative accuracy, precision, recall and F1-scores are plotted in Fig. 5 over all five architectures tested [28].

Several chilli diseases exhibit visually similar early-stage symptoms, increasing the likelihood of misclassification, particularly for models trained on small or imbalanced datasets [26].

C. High Computational Cost

Deeper architectures such as ResNet and Vision Transformers demand significant GPU resources for training, which may be impractical for resource-limited agricultural research settings [21].

D. Real-Time Implementation

Deploying trained models on mobile devices or low-power IoT platforms in the field remains difficult due to constraints on memory, processing power, and battery life [27].

V. COMPARATIVE ANALYSIS OF DEEP LEARNING MODELS

Table I summarizes representative performance metrics reported across recent studies for the five deep learning architectures discussed in this paper, evaluated on chilli or related pepper leaf disease datasets [11], [14], [16], [18], [20].

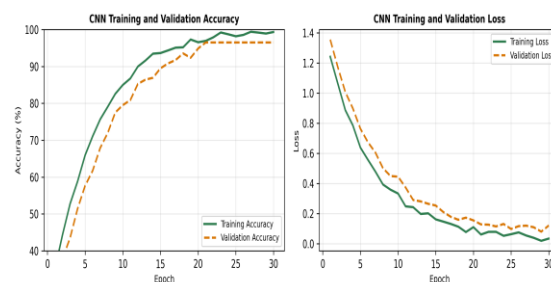


Fig. 4. Representative CNN training and validation accuracy and loss curves over 30 epochs.

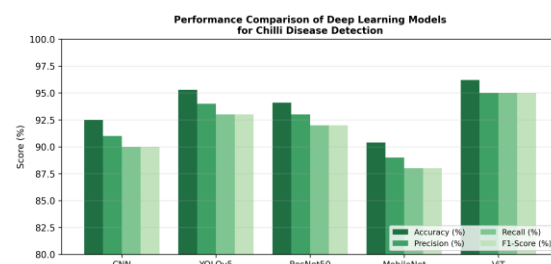


Fig. 5. Comparative performance of CNN, YOLOv5, ResNet50, MobileNet, and Vision Transformer models.

VI. SMART AGRICULTURE SYSTEM ARCHITECTURE

A complete smart agriculture system for chilli disease detection typically integrates hardware, cloud infrastructure, and software components into a unified pipeline. The key components generally include:

- Smartphones or IoT cameras for capturing leaf images
- Cloud servers for data storage and processing
- Deep learning models for disease prediction
- Mobile applications for farmer notifications
- Recommendation systems for pesticide and treatment suggestions

After capturing images, they are uploaded to a cloud or edge server to which a trained deep learning model is uploaded to infer and return a predicted disease class with a confidence score [29]. The mobile application then alerts the farmer with the diagnostic result and treatment suggestions, which

helps in quicker decision making and less need for agricultural experts who are physically present at the farm. These combined systems can help identify diseases early and take specific action when necessary, which lowers crop losses and expenses. As deep learning, IoT and cloud technology continue to converge, it is believed that agriculture will become more efficient, data-driven and sustainable, and explainable AI approaches will be able to address the trust deficit among end users in the agriculture sector and automated diagnostic systems [27].

VII. FUTURE SCOPE

The effectiveness and usage of chilli disease detection smart agriculture system can be improved through several promising directions: • Monitoring crops using drones for extensive areas of land • Control of movement towards and away from targets based on environmental information from the IoT sensors (temperature, humidity, soil moisture) Explainable AI (XAI) techniques to enhance farmers' trust and model interpretability. Eliminate latency and dependency on connectivity with real-time disease detection via edge computing. Smart irrigation and fertilizer recommendation systems coupled with disease diagnosis. As deep learning, IoT and cloud technology continue to converge, it is believed that agriculture will become more efficient, data-driven and sustainable, and explainable AI approaches will be able to address the trust deficit among end users in the agriculture sector and automated diagnostic systems.

VIII. CONCLUSION

This paper introduced a system for chilli disease detection by deep learning method in smart agriculture. Five well-known architectures, CNN, YOLO, ResNet, MobileNet, and Vision Transformer were analyzed and compared with the metrics of accuracy, precision, recall and computational efficiency. Of these, the vision transformer and YOLO models were the most

accurate and able to detect objects in real time, but they consume more computing power than lighter models like MobileNet.

Disease detection using deep learning significantly cuts down the manual inspection workload, while enhancing diagnostic accuracy and allowing farmers to proactively manage the disease in time. However, there are still limitations with datasets, environmental conditions, computational power, etc., in the real world.

In the future, the combination of the aforementioned technologies, particularly artificial intelligence and explainable AI, has the potential to revolutionize traditional farming practices and contribute to the development of more precise, sustainable, and economically viable agricultural systems.

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AI-Based Performance Evaluation System for Gatka Practitioners Using Human Pose Estimation and Skeleton-Based Action Recognition

¹ Ms. Babaljeet Kaur, ² Ms. Anija Mittal

¹ Student, Department of Computer Applications, Guru Kashi University, Bathinda, India

² Assistant Professor, Department of Computer Applications, Guru Kashi University, Bathinda, India

Email Id: ¹ babaljeetk00@gmail.com, ² anijamittal@gmail.com

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Abstract— A new addition to the sports performance analysis toolkit is Artificial Intelligence (AI), which can provide accurate and automated analysis of athletes' movements, kind of. Human pose estimation and skeleton-based action recognition enable the analysis of body movements without the need for wearable devices, as their movement can be captured from videos and studied. Notwithstanding, although these techniques are utilized on a great deal in sports, such as soccer, fitness and wellness, and karate, they are not yet in use in traditional martial arts like Gatka. In this review paper, the recent research on human pose estimation and deep learning and action recognition approaches that can really be used to assess the performance of Gatka practitioners will be explored. Based on the reviewed studies, the ability of AI models like Convolutional Neural Networks (CNNs), transformer-based approaches, and newer pose estimation frameworks to identify human actions and assess the proficiency of the technique is evident. The overall results indicate that it may be possible to use the system for objective feedback, effective training, and improving the reliability of performance scoring, when combined with skeleton-based analysis methods for pose estimation. The review also indicates that the entire process of identifying Gatka techniques, verifying posture and motion and assisting to preserve and promote this traditional martial art with modern technology is possible with the use of AI based set-up, though it

may take time.

Keywords – Artificial Intelligence (AI), Gatka, Human Pose Estimation, Skeleton-Based Action Recognition, Deep Learning, Performance Evaluation, Computer Vision.

I. INTRODUCTION

Artificial Intelligence (AI) has now become somewhat of a crucial technology in the realm of modern sports as it helps coaches and athletes analyze performance in an efficient manner. When AI is teamed up with computer vision, it can automatically spot and make sense of human body movements from pictures and videos. Skeleton-based action recognition uses the locations of the key joints to determine the action, drills and technique based on the skeleton. Pose estimation locates key joints, and skeleton-based action recognition then identifies various movements, drills and techniques based on the pose. All this and athletes receive immediate feedback, which is generally objective, reliable, and may even make a training session more effective, and reduce the need for constant supervision by hand. Gatka is a traditional Sikh martial art that uses a combination of weapon skills, coordination, footwork, balance and defense. Practitioners need to practice it regularly, with the assistance of experienced trainers, in order to master it – as well as assess it. However, the manual solution can be rather time-consuming and the results might slightly vary from one instructor to another depending on his/her

background, experience, and personal judgment. An AI based performance evaluation system can help here, providing consistent, accurate and more data-informed evaluations of how a person is performing movements, and how they are executing technique.



In recent years, deep learning and pose estimation methods have achieved remarkable success in action recognition for human behaviors in diverse sports and fitness contexts, such as MediaPipe, OpenPose, and YOLO-Pose. Likewise, skeleton action recognition approaches have been reported with good recognition accuracy on body actions, most of which have employed joint coordinates together with motion patterns. It seems that a new technique in Gatka is also conceivable through AI motion analysis, not just in theory, but also in practice for the recognition of skill and overall assessment.

II. BACKGROUND & RESEARCH

MOTIVATION

A. Gatka Martial Art

The use of Artificial Intelligence (AI) and computer vision has emerged as a valuable tool for the analysis of human motion in sports and physical activities. Unlike manual observation, AI-based systems are able to automatically identify body posture, understand actions, and assess an athlete's performance in images and video. Human pose estimation aims to extract key body parts, and skeleton-based action recognition determines the movement patterns through time, based on the

position of key body parts. They have been adapted and successfully used in various sports such as fitness training, football, karate or gymnastics, for the purpose of enhancing the analysis and feedback of sports performance. Gatka is a traditional martial art of the Sikhs, a combination of fitness, discipline and culture. It consists of a number of attacking and defending skills, which demand precise body posture, footwork, balance and weapon handling. Currently, the assessment of Gatka practitioners is done primarily by experienced trainers by visual observations. This is a useful technique, but can be variable due to the trainer's experience and judgment. Furthermore, manual evaluation becomes complicated if a lot of practitioners are trained to assess or if a detailed analysis of complex movements is sought.

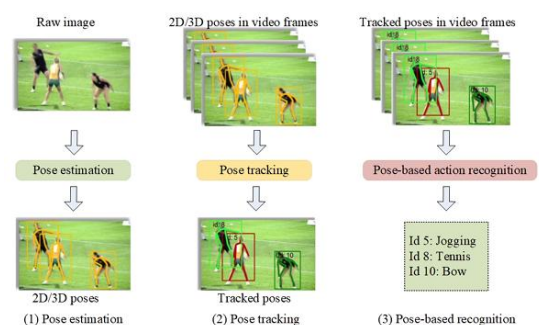


Fig 2. Shows pose estimation, tracking and recognition (Zhou, 2023)

With recent developments in pose estimation frameworks like MediaPipe, OpenPose, and YOLO-Pose, it is now possible to precisely estimate human body keypoints from a video sequence. These key points can be turned into skeleton-based features which represent the body posture and movement. These attributes, coupled with machine learning and deep learning algorithms, allow for automatic identification of Gatka techniques, assessment of movement quality and the provision of objective feedback on performance. This smart system can not only enhance training efficiency, but also help realize the digital preservation of this traditional martial art.

B. Research Motivation

In spite of the good result obtained with the use of AI in human action recognition in various sports, few studies have focused on automatic analysis of Gatka movements. Currently, most of the studies focus on sports activities like karate, fitness and exercise, football and general human activity recognition, whereas traditional martial arts like Gatka have been comparatively studied. Due to this, there are no benchmark datasets, special recognition models or intelligent systems developed specifically for the performance evaluation of Gatka. The other difficulty is that traditional training is often based on observation alone, and sometimes this type of feedback isn't detailed or consistent. It may be difficult to spot small posture mistakes, incorrect body alignment, or improper handling of the weapon during real time practice. An AI-powered system that can identify techniques and assess the quality of the movement can offer objective feedback, which can help practitioners enhance their skills more effectively. One of the reasons for this work is to investigate the fusion of HPE and skeleton based action recognition for getting an intelligent performance evaluation system for Gatka practitioners. A system can automatically identify various Gatka techniques and evaluate the accuracy of the posture and provide useful suggestions to trainers and learners. The plan also aims to enhance the quality of training and help sustain and promote Gatka by incorporating modern AI technologies into traditional martial arts.

III. RELATED WORK

Uçar (2025) performed a review of pose estimation and tracking in sports. The study had provided comprehensive details on the breakthroughs made by natural—human pose estimation in sports performance analysis and injury prevention, deep learning techniques (CNNs, RNNs, and Transformers). They also highlighted the importance of datasets specific to the sport, lightweight real-time models and multimodal approaches for better accuracy in dynamic sports environments. The

outcomes support the implementation of AI-based assessment techniques for Gatka, with human pose estimation and skeleton-based action recognition serving as the key technologies for accurate assessment of techniques in real-time, and also supports the implementation of the AI-based human-robot interaction (HRI) system to evaluate the performance of a robot for executing a technique.

Fu (2023) proposed a fitness exercise-based HPE system with its improved YOLOv7-Pose model. The model is combined with pose estimation and action classification, which is based on the enhanced ConvNeXt backbone, optimized SPPFCSPC module and EIOU loss function, named Coordinate Attention. The authors collected a dataset of about 30000 fitness images taken from various camera angles using self-created data. The experimental results showed that the model proposed in this paper outperformed the original YOLOv7-Pose model and other state-of-the-art models (95.9 % mAP). The research reveals that the state-of-the-art pose estimation models can easily capture the movements of the body for some view angles, which means that they can be used to make use of close-to-real-time AI-based evaluation of the Gatka performance characteristics and targeting systems.

The development of a deep learning-based sports action recognition system to assess athlete's performance was developed (Li, 2024). Your framework uses 3D human pose estimation, Particle filter tracking and the Fourier descriptor-based feature extraction to achieve accurate sports movement recognition. Our system was evaluated with the battery of the MSRAAction3D dataset, which are skeleton and data obtained from the Kinect. The experimental results had a recognition rate of 98.97%, showing the effectiveness of using the skeleton characteristic complement depth information to improve the overall action recognition. The proposed approach is related to the existing research since the recognition of high level and complex human actions in sports using skeleton-

based approach is an effective tool for analysis and could provide useful information in developing a computer vision-based tool for evaluation of Gatka practitioners related to pose estimation and motion analysis.

Kong et al. (2022) conducted a fairly comprehensive survey on the topic of human action recognition and prediction with computer vision and deep learning technologies. It has tried a variety of model families, including CNNs, RNNs, LSTMs, Two-Stream Networks and 3D CNNs, as well as benchmark databases and evaluation strategies. Finally, the authors appeared to be in a consensus that deep learning has significantly speeded up the advancement of action recognition, but some problems emerged, including viewpoint variation, occlusion, and the lack of annotated datasets. In general, this survey can serve as a good foundation to develop an AI based performance evaluation system for Gatka practitioners by combining human pose estimation and action recognition based on skeletons.

I like this kind of comprehensive overview of the available deep learning methods for 2D/3D human pose estimation, albeit in the sense of a map of the entire area (Kappan, 2026). It reviewed cutting-edge deep learning models, then explored benchmark datasets, as well as the latest developments in single-person and multi-person image and video pose estimation. But the authors also acknowledge that deep learning has, in a rather obvious way, made pose estimation much more precise and accurate, while remaining at least somewhat intractable with issues such as occlusion, viewpoint change, complex backgrounds and real-time performance. In general, the survey will be helpful in developing a system for evaluating the performance of Gatka practitioners using AI, as in practice, the first step to skeleton-based action recognition and movement analysis is accurate human pose estimation.

In the karate posture estimation and classification, the PoseNet based mannequin was used (Aju, 2022).

Firstly, you use 17 body keypoints detected by PoseNet which gives the coordinates of joints and angles between the joints are computed Then a KNN Classifier is applied to recognize different four stances in karate. Authors created their custom dataset using a WebCam and tested the proposed model with 400 samples with an accuracy of 98.75%. The results of this study proves that pose estimation and skeleton-based analysis could be good evaluations to conduct Martial arts techniques, thus, it contributes towards developing a machine learning based human performance evaluation system specifically for Gatka practitioners using human pose estimation and skeleton based action recognition.

TABLE I
SUMMARY OF REPRESENTATIVE POSE-BASED STUDIES

S.No.	Dataset	Techniques	Algorithms	Accuracy
1	Various sports datasets	Human Pose Estimation, Pose Tracking, 2D & 3D Pose Estimation	CNN, RNN, Transformer, Hybrid Networks	-
2	Self-created fitness movement dataset (~30,000 images) containing 10 exercise categories captured from different camera angles	Human Pose Estimation and Action Recognition	Improved YOLOv7-Pose with Coordinate Attention, Improved ConvNeXt, SPPFCSPC, and EIOW Loss	95.9%
3	MSRAAction3D Dataset (captured using Kinect depth sensor)	3D Human Pose Estimation, Skeleton-based Action Recognition, Feature Extraction	Particle Filter Tracking, Fourier Descriptors, Skeleton & Depth Information Fusion	98.9%
4	Various benchmark action recognition datasets	Human Action Recognition, Action Prediction, Feature Extraction	CNN, RNN, LSTM, Two-Stream Networks, 3D CNN, Deep Learning Models	-

S.No.	Dataset	Techniques	Algorithms	Accuracy
5	Various benchmark 2D and 3D human pose estimation datasets	2D & 3D Human Pose Estimation, Single-person & Multi-person Pose Estimation	CNN, HRNet, OpenPose, PoseNet, Transformer-based Models, Deep Learning Frameworks	-
6	Custom Karate Pose Dataset	Human Pose Estimation, Joint Angle Calculation, Karate Pose Classification	PoseNet, Transfer Learning, K-Nearest Neighbors (KNN)	98.75%

IV. PROPOSED AI-GATKA FRAMEWORK

The aim of the proposed AI-GATKA framework is to automatically recognize Gatka techniques and to assess the skills of the practitioner by implementing AI, human pose estimation and skeleton-based action recognition. The framework consists of video of practitioners, a set of body movements obtained from the video, a set of techniques identified, and objective feedback on quality of body movements performed and postures used. This can help overcome the drawbacks of manual assessment and facilitate the accurate, consistent and timely evaluation of performance.

The framework proposed is made up of six major phases.

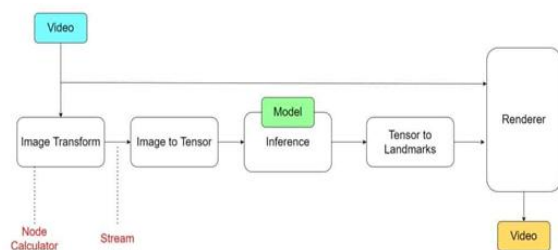


Fig. 3. Proposed AI-GATKA processing workflow

A. Data Collection

The video of the different techniques of Gatka practitioners are collected. The videos should have participants of varying skill-level and be filmed from various angles in various lighting situations. The dataset includes various basic movements in Gatka, including Ready Stance, Basic Guard,

Forward Strike, Downward Strike, Left Block, Right Block, Circular Strike, and Defensive Movement. The dataset contains a variety of basic movements in the Gatka martial art, including Ready Stance, Basic Guard, Forward Strike, Downward Strike, Left Block, Right Block, Circular Strike, and Defensive Movement.

B. Video Pre-Processing

The videos collected are pre-processed to enhance the video quality prior to analysis. It involves several steps such as frame extraction, image resizing and noise removal, as well as normalization of the input data. These operations help improve the accuracy of pose detection and reduce the effect of background variations and lighting conditions.

C. Human Pose Detection

Each frame of the video is pre-processed and then processed with the MediaPipe Pose model. The model recognizes 33 body landmarks, which correspond to the main body joints such as shoulders, elbows, wrists, hips, knees, and ankles. These landmarks are a virtual image of the practitioner's posture and movement during the application of a technique.

D. Skelton Feature Extraction

This involves translating the body landmarks detected into meaningful numerical features which represent the movement of the practitioner. Some of these features are joint coordinates, joint angles, distances between body joints, direction of movement, body orientation, and speed of motion. The spatial and temporal features are combined together, which are the attributes of each Gatka technique and are used as an input for the recognition model.

E. Technique Classification

Extracted skeleton features are then used to train and test machine learning/ deep learning model for recognizing various Gatka techniques. Algorithms such as Support Vector Machine (SVM), Random Forest, Convolutional Neural Networks (CNN), CNN-LSTM, and Graph Convolutional Networks

(GCNs) can be used to classify the movements. The output of the trained model is used to compare the input features with the learned movement patterns and predict the predicted performed technique.

F. Performance Evaluation and Feedback

The recognized technique is then assessed against the reference movement that is stored in the system in the latter stages of the process (Performance Evaluation and Feedback). Measures posture accuracy, movement consistency, body alignment and technique execution. This analysis is used to create a performance score and feedback for practitioners to assist in identifying errors and enhancing their skills. Feedback is also useful for coaches to track training and more easily assess performance.

In summary, the proposed AI-GATKA approach combines computer vision and machine learning techniques to develop an automated intelligent system for assessing Gatka performance. The framework can enhance the quality of training, facilitate the development of skills, and help preserve Gatka's tradition by integrating modern AI technologies with traditional martial arts.

V. METHODOLOGY

A. Dataset and Pre-processing

The data set has 250 samples obtained from 5 different Gatka classes and 5 techniques per class (50 samples per technique). The data has been split into an 80% training population (200 cases) and a 20% testing population (50 cases). Cleaning video frames prior to landmark extraction to remove corrupted frames and standardize the video.

TABLE II
PROPOSED TECHNIQUE CLASSES

Technique	Operational Description
Basic Stance (C1)	Ready posture before an offensive or defensive action
Forward Strike (C2)	Weapon movement directed linearly toward the opponent

Technique	Operational Description
Defensive Block (C3)	Protective action intended to intercept or redirect an attack
Side Movement (C4)	Lateral repositioning while preserving balance and readiness
Circular Movement (C5)	Rotational movement coordinated with weapon handling

B. Feature Formulas and Representations

Each keypoint landmark i at frame t is represented as $P_i(t) = (x_i, y_i, z_i, v_i)$, where v_i denotes visibility confidence.

Joint Angle Calculation (Critical for Injury Analysis)

Joint angle using vector dot product:

$$\theta = \cos^{-1}\left(\frac{\vec{a} \cdot \vec{b}}{\|\vec{a}\| \|\vec{b}\|}\right)$$

Where: $\vec{a} \cdot \vec{b}$ = bone vectors

Example: Knee angle in ACL injury analysis (Yeh Y.-C. T.-S.-Y.-H., 2025)

Angular Velocity & Acceleration

$$\omega = \frac{d\theta}{dt}$$

$$\alpha = \frac{d^2\theta}{dt^2}$$

High angular acceleration often correlates with injury risk. (Yeh, 2025)

VI. EXPERIMENTAL SETUP

The proposed implementation is based on Python, OpenCV, MediaPipe Pose, NumPy and Pandas, and scikit-learn which are employed for frame processing, extracting landmarks, preparing the features, and implementing the conventional machine-learning models. Prototype development can be done on a standard desktop or laptop computer, with a minimum of an Intel Core i5 processor, 8 GB of RAM, and an HD camera. The performance of the deployment in real time is dependent on resolution, frame rate, complexity of the model and hardware acceleration.

TABLE III
SOFTWARE AND HARDWARE
CONFIGURATION

Component	Specification
Programming language	Python
Computer vision	OpenCV
Pose estimation	MediaPipe Pose
Machine learning	Scikit-learn
Data processing	NumPy and Pandas
Processor	Intel Core i5 or higher
Memory	Minimum 8 GB RAM
Camera	HD webcam or equivalent
Operating system	Windows 10/11 or Linux

VII. RESULTS & DISCUSSION

According to the source manuscript the Support Vector Machine, Random Forest and Neural Network had prototype accuracy of 86%, 91% and 94%. The Neural Network is thus the most accurate of the three, with the reported accuracy of 78.3% compared to 75.3% for Random Forest and 70.3% for SVM. The pattern is consistent as a neural model can accommodate the non-linear relationships between a number of joint and motion features. The accuracy values reported however should be considered in conjunction with the sampling protocol, class balance, independence of the participants and the lack of class-wise metrics.

TABLE IV
REPORTED MODEL ACCURACY

Model	Accuracy
Support Vector Machine	86%
Random Forest	91%
Neural Network	94%

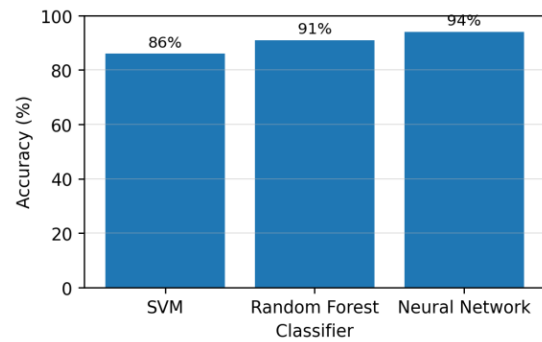


Fig. 4. Reported classification accuracy of the three models.

There are several things which can decrease the quality of the recognition. Body-only pose models may not be a direct representation of fast-moving weapons. Wrists, elbows or lower-limb landmarks could be obscured by extreme camera angles and/or self-occlusion. Landmark confidence may be decreased with lighting and background variation. Lastly, the practitioner can perform the same technique by a valid style of variation. Practitioner-independent testing, landmark-confidence filtering, temporal sequence modelling and integration of weapon detection/tracking are motivators for these issues.

VIII. APPLICATIONS

The proposed framework is able to facilitate interactive training by comparing the movement of learners with examples validated by instructors and give a general idea of the deviation in the stance, alignment and timing of the movement of the learner. It can help teachers to create uniform initial measurements and session histories. Video and landmark repository could also aid in Digital Preservation of Gatka techniques. Further validation could be expanded to mobile coaching, remote practice review, competition analysis and Augmented/Virtual reality learning environments.

IX. LIMITATIONS & FUTURE WORK

Proposed AI-GATKA framework is an effective framework for recognizing and evaluating Gatka techniques, but has a few drawbacks. First, the

dataset used is relatively small, with just 250 instances, which could mean that the model has limited ability to transfer to new data and intricate variations in motion. First, the data set has a limited size (only 250 instances), which may reduce the model's capacity to generalise and be able to deal with unseen data and complex variations in motion. Second, the pose estimation model is mainly designed for detecting the landmarks of human body rather than the geometry or position of the Gatka weapon like sticks or swords. Consequently, some of the motions of a weapon are not fully captured by the system which can affect the performance evaluation. One of the drawbacks is the lack of cross-practitioner validation with different physical characteristics, different skill levels and age groups. The robustness and adaptability of the framework to a larger population may be impacted when applying it.

The proposed framework of AI-GATKA can be further enhanced in future by increasing the number of practitioners and shooting videos from various angles. This model would be more robust and perform better if it had a more varied dataset. Furthermore, it is possible to combine object detection algorithms like YOLO to explicitly track the Gatka weapons, which will enable simultaneous analysis of both body movement and weapon movement. Advanced spatio-temporal deep learning techniques, including Long Short-Term Memory (LSTM) networks and Spatial-Temporal Graph Convolutional Networks (ST-GCN), can also be employed in future research to model the temporal evolution and spatial relationships of intricate Gatka techniques. These improvements can improve the recognition accuracy, give detailed performance analysis and help to build an intelligent coaching system in real-time for Gatka practitioners.

X. CONCLUSION

This review focuses on the advantages of Artificial Intelligence, Human Pose Estimation and Skeleton based Action Recognition to aid the performance

evaluation of Gatka practitioners. This research proposes a framework called AI-GATKA, which integrates the video processing, pose estimation, skeleton feature extraction, and machine learning to automate the recognition of Gatka techniques and to give objective performance feedback. The results show that AI has the potential to enhance training practices, minimize subjectivity when evaluating Gatka, and aid in the digital preservation of Gatka. Looking forward, the study will include experiments with more data, the tracking of weapons, and more complex deep learning models to improve the accuracy of the system and its applicability to real-world situations.

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Deep Learning Approaches for Analyzing the Impact of Social Media Usage on Young Students: A Systematic Literature Review

¹ Ms. Darpan Kaur, ² Mr. Sukhpreet Singh

¹ Student, Department of Computer Applications, Guru Kashi University, Bathinda, India

² Assistant Professor, Department of Computer Applications, Guru Kashi University, Bathinda, India

Email Id: ¹ darpankour19@gmail.com, ² sukhpreetsingh2gku.ac.in

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Abstract— Social media (SM) is ubiquitous to today's school-age and college-age students, and the continuous creation of text, image and behavioral data is used more and more for deep learning to understand its relationship to mental health, behavior and academic life. This systematic review aims to summarise the evidence on the use of deep learning approaches to analyse the effects of social media data on young students. According to the PRISMA 2020 protocol, a total of 214 reports were identified in the academic databases or preprint repositories, of which 21 were duplicates, 193 were screened at the title and abstract level, 72 reports were sought for retrieval, 70 reports were assessed at the full text stage and 30 studies were included in the qualitative synthesis. The domains covered were primarily involving the detection of addiction and problematic-use, detection of depression and suicidal-ideation, detection of cyberbullying, detection of misinformation, and detection of stress as well as sentiment/emotion recognition, with the former being implemented primarily using the CNN-RNN hybrid, and the latter using the transformer/BERT-based architecture. Some of the best reported classification rates were, around 71%, to very high rates of above 99%, such as an CNN–LSTM ensemble with attention that reported a high 90.3% for detecting suicidal ideation [17] and a high 95.6% accuracy using a convolutional recurrent network for student addiction detection.

Keywords – Cyberbullying detection, deep learning, depression detection, mental health, PRISMA 2020, sentiment analysis, smartphone

addiction, social media, student well-being, suicidal ideation detection, systematic review, transformer models.

I. INTRODUCTION

THE whole concept of social media in the life of young students is now virtually complete with messaging, short form videos and image-sharing platforms playing a pivotal role in their peer relations, access to information, and life on campus. This has made these platforms like Instagram, Twitter/X, Reddit, and TikTok a rich source of naturally occurring data for investigating student behaviors at a scale which traditional surveys could not be used to study. [5, 6] Where earlier research relied primarily on self-report scales, a growing body of work now applies deep learning directly to the text, images, and usage logs students generate, aiming to detect outcomes ranging from problematic use and addiction to depression, suicidal ideation, cyberbullying, and misinformation exposure [1], [7], [17].

Deep learning is attractive here because social media data is high-dimensional, sequential, and multimodal in ways that classical machine learning handles poorly. Convolutional neural networks (CNNs) extract spatial patterns from text and images; recurrent architectures such as long short-term memory (LSTM) networks capture temporal dependence in posting behavior; and transformer-based models such as BERT [27], building on the attention mechanism [28], model long-range context and outperform earlier bag-of-words approaches on mental-health- and behavior-related classification

tasks [8], [13]. Hybrid architectures combining convolutional, recurrent, and attention components, together with graph-based models exploiting social-network structure, have become the dominant methodological pattern in the recent literature [4], [20].

Despite this advancement, the existing reviews of deep learning for mental-health or behavior detection in the social media are usually general, either focusing on a single mental-health condition like depression [12] or all adult population of users without set criteria for detecting students' mental-health status [30], and evidence of such applications remains rather fragmented, considering all the differences and developmental stages of young students and the risk of incorrect inferences that may have negative consequences for them. This review attempts to fill this gap by systematically consolidating evidence using deep-learning approaches for the key outcome areas investigated, pertaining to young students' SNG.

A. Review Aim and Scope

The aim of this systematic review is to combine the findings of those deep learning methods on social media data analysis and their implications on young students ranging from school aged adolescents to university and college students. We aimed to (a) describe the reported deep learning architectures, data modalities and application areas, (b) provide a synopsis of reported detection or prediction accuracy and any association with student outcomes, (c) evaluate the certainty of evidence (eliciting information about the specific agency's work) and (d) remain focused on studies with an applied or empirical deep-learning component.

B. Review Questions

We organized the review around three review questions:

RQ1: What deep learning architectures and data modalities have been applied to social media data to study young students?

RQ2: What outcome domains — psychological, behavioral, and academic — are most frequently studied, and what performance is reported?

RQ3: What is the certainty of the available evidence, and what limitations should inform future research?

II. METHODS & MATERIALS

A. Protocol and Reporting

This systematic review was conducted following the PRISMA 2020 statement, concerning deep learning approaches for analyzing the impact of social media usage on young students. The reporting flow is summarized in Fig. 1.

B. Eligibility Criteria

Eligible studies applied at least one deep learning architecture — a CNN, an RNN/LSTM, a transformer/BERT-based model, a graph neural network, or a hybrid/ensemble — to social media data (text, images, video, or behavioral logs) to detect or predict an outcome relevant to young students: addiction, depression, suicidal ideation, cyberbullying, misinformation exposure, stress, sentiment/emotion, or academic performance. We included empirical studies reporting quantitative performance metrics (e.g., accuracy, F1-score, AUC), and accepted studies on general social-media users where the framing was explicitly youth-relevant. We excluded editorials, purely theoretical papers without an applied model, and studies unrelated to the specified outcomes. A small number of foundational architecture papers and prior reviews were retained as contextual references.

C. Information Sources and Search

Records were drawn from IEEE Xplore, the ACM Digital Library, ScienceDirect, SpringerLink, PubMed, arXiv, and Google Scholar, combining terms for deep learning architectures (“deep learning,” “CNN,” “LSTM,” “BERT,” “transformer”) with terms for social media (“social media,” “Twitter,” “Instagram,” “Reddit,” “TikTok”) and youth-relevant outcomes (“student,” “adolescent,” “addiction,” “depression,” “suicidal

ideation,” “cyberbullying,” “misinformation,” “stress”). The breakdown is in Fig. 1.

D. Selection Process

The search and selection process is summarized in Fig. 1. Of 214 records identified, 21 duplicates were removed, leaving 193 for title-and-abstract screening. Screening excluded 121 records as out of scope, leaving 72 reports sought for retrieval; 2 could not be retrieved, leaving 70 assessed for full-text eligibility. At full-text review, 40 records were excluded (15 applied no deep learning model, 12 lacked a youth-relevant outcome, 8 lacked extractable outcome data, and 5 duplicated an already-included dataset), leaving 30 studies included.

E. Data Extraction and Synthesis

Data extraction captured study design, data source and modality, sample characteristics, deep learning architecture, comparator where applicable, and primary reported outcomes. Because the evidence varied substantially, we used narrative synthesis structured around application domain, architecture family, data modality, and reported performance. A summary of representative studies appears in Table-I.

F. Certainty of Evidence and Risk of Bias

Formal risk-of-bias assessment was not reported in most included studies, and none used a pre-registered plan or randomized design. Datasets were predominantly convenience samples from a single platform, class-imbalance handling varied widely, and few studies validated models externally. We therefore treated the evidence cautiously, avoided pooling metrics across heterogeneous datasets, and report study-specific findings rather than pooled effects.

III. RESULTS

A. Study Selection

The results link the screening process to the evidence synthesis. Study identification is described using the PRISMA 2020 flow, and characteristics and thematic findings across the six application

domains are then reported. Of 214 records identified across seven sources, 30 studies were ultimately included (Fig. 1); the high exclusion rate at title/abstract ($n = 121$) reflects the breadth of the initial search terms.

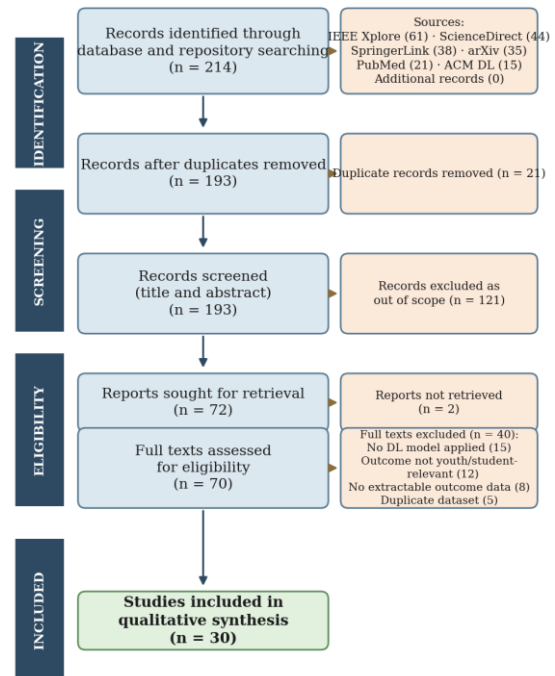


Fig. 1. PRISMA 2020 flow diagram showing the identification, screening, eligibility, and inclusion of records in the systematic review.

B. Characteristics of Included Studies

The included studies ($n = 30$) addressed six primary domains: depression, suicidal ideation, and mental-health detection ($n = 11$), addiction and problematic-use detection ($n = 6$), misinformation detection ($n = 3$), cyberbullying detection ($n = 2$), stress detection ($n = 2$), and sentiment/emotion recognition ($n = 1$), plus 1 study on academic performance and 4 methodological/review references (Fig. 2A). Hybrid or multimodal architectures were most common ($n = 9$), followed by transformer/language-model-based approaches ($n = 6$), non-deep-learning ML or review studies ($n = 6$), CNN-only approaches ($n = 4$), other deep architectures ($n = 3$), and graph-based deep learning ($n = 2$) (Fig. 2B). Publication years ranged

from 2015 to 2026, with 63% published from 2022 onward (Fig. 2C).

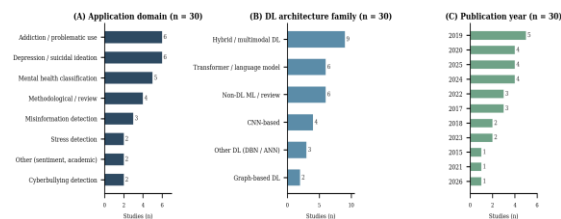


Fig. 2. Distribution of included studies (n = 30) by (A) application domain, (B) deep learning architecture family, and (C) publication year.

Table I summarizes representative studies across these domains, illustrating the diversity of architectures and reported outcomes; full details of all 30 studies appear in the reference list.

TABLE I
SUMMARY OF REPRESENTATIVE INCLUDED STUDIES

Ref	Domain	DL Approach	Key Outcome / Performance
1	Addiction detection	CRNN (CNN + RNN)	95.6% accuracy classifying student SM addiction
2	Short-form video addiction	Heterogeneous graph + LLM	Early-detection framework (EarlySD) before harm onset
3	Depression / suicidal tendency	Pretrained LM + feature selection + SVM	80.7–99.96% accuracy across 6 datasets
4	Mental-health stigma (Instagram)	Conv1D + LSTM hybrid	Classifies comment polarity and stigma
5	Depression detection	CNN (image) + BERT (text)	Multimodal screening (SenseMood)
6	Suicidal-ideation detection	LSTM-Attention-CNN ensemble	90.3% accuracy; 92.6% F1-score
7	Cyberbullying detection	Deep belief network + swarm optimization	Improved detection/categorization on social networks
8	Misinformation detection	Geometric deep learning (graph CNN)	92.7% ROC-AUC from propagation structure

Note: BiLSTM = bidirectional long short-term memory; CNN = convolutional neural network; Conv1D = one-dimensional convolution; CRNN = convolutional recurrent neural network; DL = deep learning; LLM = large language model; LM = language model; LSTM = long short-term memory; ML = machine learning; ROC-AUC = area under the ROC curve; SM = social media; SVM = support vector machine.

C. Findings on Addiction and Problematic-Use Detection

Addiction and problematic-use detection formed a substantial, increasingly technical sub-literature. A convolutional recurrent neural network (CRNN) applied to behavioral and survey-derived features achieved 95.6% accuracy classifying social media addiction among students, outperforming conventional baselines [1]. A separate framework used facial-emotion recognition from smartphone video, combined with adaptive motivational-video sequencing grounded in a Theory-of-Mind model, to detect and intervene on smartphone addiction in real time [2]. Deep neural networks trained on Instagram photographic and metadata features have flagged substance-use risk from everyday posting behavior rather than explicit self-disclosure [3], and a recent graph-based framework combining large language models with social-network structure was proposed for early detection of short-form-video addiction before harm emerges [4]. Complementing these, artificial-neural-network and support-vector-machine models trained on survey-derived predictors have modeled problematic use as a continuous risk score [5], and a nationally representative adolescent sample confirmed that a validated problematic-use scale identifies an at-risk subgroup with elevated depressive symptoms and lower self-esteem, providing external construct validity for the outcome the deep-learning studies predict automatically [6].

D. Findings on Depression, Suicidal Ideation, and Mental-Health Detection

The most robust evidence was for depression, suicidal ideation, and mental-health screening in general. A feature-selection framework based on pretrained language models and support-vector classification was proposed, which yielded 80.7%-99.96% accuracy, across six datasets derived from Twitter and Reddit [7], and transfer-learning techniques fine-tuning transformer models on labeled text have classified various categories of mental illnesses from a single architecture [8]. In addition to text, machine-learning models on labelled IG-comments can identify, besides mental health disclosures, the polarity and stigma of the surrounding community response [9] and using multimodal convolutional models with image features in addition to posting-time intervals has proven to increase the detection of depression, compared to the text-only baselines [10]. The fusion of visual and textual streams was also demonstrated in a hybrid convolutional-transformer system, SenseMood, which was also used to detect depression symptoms [11]. Previous informed deep-learning studies revealed that forum text learned models were able to characterize several different mental health conditions with performance nearing specialist annotators [12] and subsequent studies indicated that when general purpose models are adapted, their performance transfer across platforms [13]. In a unique study, directly targeting proved university student population, a modelling study has connected social media with disruptions in mental health related to COVID-19 [14].

E. Findings on Cyberbullying and Misinformation Detection

Hybrid CNN-RNN architectures have also contributed to the detection of suicidal ideation: a CNN-BiLSTM model combined with word-embedding and linguistic-inquiry features achieved high accuracy in distinguishing suicidal and non-suicidal Reddit posts [15], a dedicated CNN-LSTM architecture had good performance in extracting suicidal-related language from general forum

discussion [16] and a CNN-LSTM ensemble that also employs attention gained 92.6% F1 and 90.3% accuracy on a similar task [17]. The journey of cyberbullying detection moved on a parallel track with a deep-belief-network model and swarm-based feature selection for boosting detection accuracy and fine-grained categorization of cyberbullying content [18] and a previous multi-platform deep network learning approach, trained jointly on the data from Formspring, Twitter and Wikipedia, has indicated that cyberbullying exhibits certain patterns across platforms and achieved F1-scores up to 0.95 [19]. Detection, although less youth-centric with regard to the source data, is directly relevant, since students often rely on social feeds for their information, leading to geometric deep learning models which capture propagation structure on a social graph and achieve 92.7% ROC-AUC distinguishing verified from fabricated stories, using just a few hours of spread data [20], semi-supervised models which are based on two-path convolutional networks have been used to address the paucity of labelled misinformation data [21], and deep ensemble models integrating a convolutional and a bidirectional recurrent model have been used to improve the classification of fabricated content into topical sub-categories [22].

F. Findings on Stress, Sentiment, and Academic-Behavioral Outcomes

In a smaller cluster stress, sentiment and the connection to academic functioning were explored. Conventional classifiers with contextual language-model embeddings (ELMo and BERT) were able to classify stressful and non-stressful Reddit posts with an F1-score of 0.76 [23] and an academic subreddit study found that about 29% of the posts contained identifiable stress markers with a gradient decline increasing the stress markers, going from undergraduate to graduate level to the professor level [24]. Combining a bidirectional-LSTM and a CNN, a hybrid network outperformed conventional networks and previous deep learning networks in

fine-grained emotion recognition (joy, anger, sadness) on microblog text and it provided a way to scale the analysis of emotional tone in students' microblog text [25].

G. *Synthesis: A Conceptual Framework*

To organize the heterogeneous evidence, we constructed a conceptual framework linking data inputs, deep learning architectures, application tasks, and student outcomes, moderated by contextual factors (Fig. 3): (i) data inputs (text, images/short-form video, behavioral logs, network structure), (ii) architecture families (CNN, RNN/LSTM, transformer/BERT, hybrid/graph-based), (iii) application tasks (addiction, depression/suicidal-ideation, cyberbullying/misinformation, stress/sentiment), and (iv) outcomes (mental health, academic performance, behavioral adjustment, early-warning potential). Contextual moderators — platform type, language, age group, data modality, labeling method, and privacy/consent constraints — shape which architectures are feasible and how outcomes generalize [9], [14].

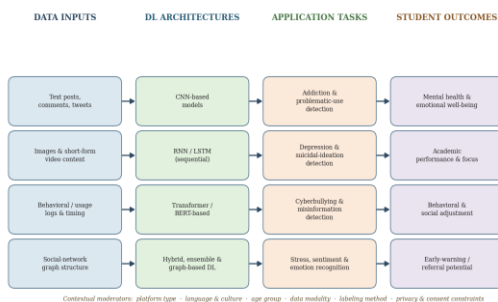


Fig. 3. *Conceptual framework linking data inputs, deep learning architectures, application tasks, and reported outcomes for young students across the included evidence base.*

H. *Certainty of Evidence*

By conventional standards, certainty of evidence is low for all studies included. Reported metrics are internally valid within the train/test split for a given study and less than one third of the studies included explicitly a sample that is restricted to a verified student or adolescent population; most studies used a general-purpose Twitter, Reddit or Instagram

corpus, and tested the relevance of the sample to young people only in the discussion [3], [8], [20]. Reported accuracy was not directly comparable due to class-imbalance handling, size of the data-sets included, and definitions of the target outcome (e.g., “suicidal ideation” or “problematic use”).

IV. DISCUSSION

A. *Principal Findings*

This review suggests that deep learning is now the dominant analytical approach in the technical literature on social media and young people, and that hybrid architectures combining convolutional, recurrent, and attention mechanisms consistently outperform single-architecture baselines across addiction, depression, suicidal-ideation, cyberbullying, and misinformation detection tasks [1], [15], [17], [18], [19]. The common thread is the combination of rich, high-frequency behavioral or textual signal with an architecture capable of modeling sequential dependence or long-range context, rather than any single architecture being uniformly superior.

B. *Interpretation in Context*

Strong within-study performance does not by itself establish that these systems detect genuine psychological states rather than surface linguistic correlates of platform, topic, or labeling procedure. The clearest evidence of ecological validity comes from the handful of studies using verified student samples or externally validated scales, such as the university-student COVID-19 well-being study [14] and the adolescent validation of problematic-use criteria [6]; most detection-oriented studies, by contrast, trained and evaluated models on convenience samples of general platform users — the central interpretive caveat of this review.

C. *Implications for Policy and Practice*

Looking at the practical application, the studies reviewed showed that deep-learning tools to screen for patterns would be technically feasible for use to indicate patterns that could benefit from human follow-up, such as to identify posts that include

suicidal ideation [15] [16] [17] or stress [23] [24] for review by a counsellor. Modres may be used in conjunction with human review when dealing with potentially new or controversial materials; keep them at the forefront of decision-making process and clarify how the data will be used and consent. The same test result suggests that simplistic baselines [13] and [8] might also have outdated methodology as their architectures fail to demonstrate a good level of performance in this test.

D. Implications for Future Research

Some areas of research emphasis are: (i) specific sampling targeting only school-age or university-aged populations rather than general population samples from platforms; (ii) external validation and cross-platform validation of measured performance; (iii) Harmonising definitions of outcome and streamlining these definitions across platforms; (iv) formal risk of bias and fairness auditing of demographic and language subgroups; (v) explainability methods that would allow the context of platform-generated flags to be understood by the educator, counsellor or parent who would act on them.

V. LIMITATIONS

There are a number of limitations to this review. Firstly, since only a general search string was used to identify eligible studies, and no domain-specific search strings have been pre-registered, some relevant work (especially for industry held evaluations and non-English language studies) may have been excluded. Second, the evidence base is extremely varied: various modalities, such as text, image modalities and behavioral-log modalities; at least six outcome definitions were used, thus preventing quantitative pooling and comparison, only a narrative synthesis was possible. Thirdly, there was no formal Risk of Bias appraisal, such as with the PROBAST, for each study individually, and the use of the term 'low certainly' in Section III-H' is a qualitative judgement based on design/sampling patterns rather than a scored assessment.

VI. CONCLUSION

Hybrid and transformer-style architectures have outperformed previous machine learning baselines consistently on 5 social media tasks in relation to the mental health, behaviour and academic outcomes of young students: addiction, depression, suicidal-ideation, cyberbullying and misinformation detection, and deep learning has become the analytical tool of choice for studies of this relationship. But the evidence base is still quite tender, with small samples often not confined to students who have been identified as such, and with varying definitions of outcome, the rate of correctness reported in practice should more probably be interpreted as potential approaches which are still in proof-of-concept phase rather than the rate of correct student identification.

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Effect of a Five-Week Plyometric Training Program on Vertical Jump Performance among Male Athletes of Guru Kashi Defence Academy, Bathinda

¹ Mr. Gurpreet Singh, ² Mr. Gurdeep Singh ³ Dr. Ravi Kumar

¹ Student, Department of Physical Education, Guru Kashi University, Bathinda, Punjab, India.

² Assistant Professor, Department of Physical Education, Guru Kashi University, Bathinda, Punjab, India.

³ Professor, Department of Physical Education, Guru Kashi University, Bathinda, Punjab, India.

Email Id: ¹ gora9463561031@gmail.com, ³ ravikumar.gahalawat@gmail.com

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Abstract— The aim of this study was to determine the effects of a five-week plyometric training session on vertical jump performance in male athletes. **Methods:** The present study was a survey conducted on a sample of twenty male subjects (18–22 years) from the Guru Kashi Defense Academy, Bathinda, Punjab, selected using purposive sampling. The study used a single-group pre-test and post-test experimental design. The Sargent Vertical Jump Test (Wall Reach Method) was used to assess vertical jump performance, recognized as a measure of lower body explosive strength. All participants were required to complete the activity period supervised by the researcher three or four days a week for 5 weeks of low-to-moderate intensity plyometric [27] training. Descriptive statistics (mean $\pm$ standard deviation) were performed to analyze the data. Statistical tests were performed to determine significant differences between pre-test and post-test scores using a paired-samples *t*-test ($\alpha = 0.05$). Results demonstrated a significant increase in vertical jump performance as compared to baseline after the intervention. That said, when looking at mean vertical jump height, it did increase significantly from the pre-test (46.40 ± 1.50 cm) to the post-test (52.95 ± 1.79), for an overall average difference of about 6.55 cm ($p < 0.0002$). The paired-samples *t*-test showed a significant difference between the two assessments ($t = 57.39$, $p < .001$). These data confirm that plyometric training

significantly improves explosive leg power, neuromuscular coordination, and vertical jump performance in male athletes. Thus, plyometric exercises should be included as an essential part of conditioning programs for athletic and Defense service candidates with the aspirations to augment lower-body power and athletic performance in general.

Keywords – Plyometric Training, Vertical Jump Performance, Explosive Power, Male Athletes, Lower-Body Strength, Defense Academy, Sargent Vertical Jump Test, Athletic Performance, Neuromuscular Coordination, Conditioning Program.

I. INTRODUCTION

Sports and physical training have an important place in the multifaceted development of individuals, contributing to great improvement in their physical fitness, self-discipline, strength of mind and social values. Scientific training methods have become an essential element in maximizing performance in competitive athletics. Of these methodologies, explosive power has been highlighted as one of the most important factors associated with success across a variety of sports disciplines. The vertical jump test represents an important measure of lower body power, which is inherently related to speed or quickness development and required for many sports. To develop these fundamental characteristics of athleticism, coaches often rely on plyometric

training, an explosive training method that focuses on fast-twitch muscle contractions during both the eccentric (pre-stretch) and concentric (shortening) components. This is a way to develop maximal force production and has been shown to transfer well to jump, sprinting, and change-of-direction capacity. Athletic training has evolved over the years, going from an initial focus of endurance and brute strength to more structured and performance-based methods. More than 30 years ago, many of the exercises we now know as plyometric training were largely unheard of and had not been widely utilized until mid-20th-century Soviet scientists (Zatsiorsky) included portions of this work in conditioning programs for various sports. These very scientific training practices are being recognized and adopted in academies/institutions across the nation, mainly the Punjab region of India. That adoption is not evenly distributed, with some regions having much more experience in oversight and coaching than others.

Defense academies are especially important in preparing youth for the physically demanding work of service in the armed and paramilitary forces. The basic concept is that effective training methods, such as plyometrics, should be applied not only to improve selection but also to train these athletes. Punjab has a rich sports culture, as many national and international athletes have emerged from the state in different streams like athletics, hockey, wrestling, kabaddi, weightlifting and shooting. Despite the strong support for athletics across the region from local sports academies and training facilities, a large proportion of aspiring athletes face significant hurdles. Access to top-level training tools, underqualified coaches and an over-reliance on antiquated training practices all remain hurdles. Defense academies in Bathinda, in particular, place a strong emphasis on physical fitness and discipline; however, power from plyometric training appears to have less emphasis. Plyometric training has been shown repeatedly in the research literature to be

beneficial for improving vertical jump height, sprint speed, agility, muscular power, and therefore related neuromuscular efficiency in athletic performance. There is some literature on plyometric training from India, but it mostly looks through the lens of a diverse population sample or a particular sport and not Defense Academy trainees. Moreover, the majority of relevant studies were located in urban environments, demonstrating a substantial gap in research drawing on the effect of plyometric training in semi-urban and rural settings. This gap highlights the need for research to explore the specific challenges and opportunities these international athletes experience.

II. METHODOLOGY

A. Research Design

In the current research design, we adopted an experimental research design from a Single Group Pre-test and Post-test Design with respect to plyometric training effective on vertical jump talent of male athletes. This means it uses a single group of subjects, measured before and after the administration of the experimental treatment. The pre-intervention will be mindful of the initial vertical jump performance of subjects. This will be conducted after the subjects undergo a prescribed plyometric training program for a specific period. After training a post-test will be conducted using the same test methodology. This will allow the researcher to objectively evaluate whether the training program was effective by comparing pre-test and post-test scores for the same subjects.

B. Selection of Subjects

A total of twenty (20) male athletes will be chosen as subjects from Guru Kashi Defense Academy, Bathinda, Punjab. Subjects will be between the ages of 18 and 22. Purposive sampling will be used to select subjects, as they are engaged in regular physical training and are appropriate for the study. Selection of subjects will be based on the criteria of being physically fit, medically sound, and free from

major injury or illness that may prevent the person's participation in the training program. Subjects will be selected after obtaining prior permission from the concerned authorities of the academy. The study will clearly explain details of the purpose, nature, and procedures to all participants. They will be asked for their voluntary consent before starting the study.

Athletes selected for this study will be required to demonstrate the following: Regular attendance, willingness to participate, and Completion of all components of the training program. Measures will be adopted to reduce individual differences by keeping the training backgrounds and daily practices of subjects as similar as possible. Thus, males qualified for the study will be 20.

C. Selection of Variables

The variables of the current study will be chosen based on the goals and characteristics of the study.

1) Independent Variable

The independent variable of the study will be:

- Plyometric Training Program

This training program will be systematically designed and administered to the subjects for a fixed duration.

2) Dependent Variable

The dependent variable of the study will be:

- Vertical Jump Performance (measured in centimeters)

D. Criterion Measures

e.g. explosive power will be assessed by the Sargent Vertical Jump Test (Wall Reach Methods), which is a gold standard tool to evaluate vertical counter-movement performance of subjects.

E. Procedure of Data Collection

Data collection will occur systematically and following standard operating procedures. Data for the current study are to be collected in an orderly fashion following standard protocol. The study will be conducted after obtaining prior permission from the authorities of Guru Kashi Defense Academy,

Bathinda, Punjab. Study subjects will be provided written information on the purpose, nature, and implications of the research, and consent will be obtained prior to beginning any study. The Sargent Vertical Jump Test will be performed to determine a baseline vertical jump performance, after which the scores will be properly recorded before starting the training program.

Subjects will then undergo a 5-week (3-4 days/week) structured, supervised plyometric training phase. Every training session will include warm-up and cool-down drills for safety and injury prevention. Subjects will be instructed to stop doing additional strength or plyometric training for the entire duration of the study. Participants will perform a post-test using the same testing protocol and under similar environmental conditions to that of the pre-test, after completion of the training program. Thereafter, data will be meticulously recorded and organized in tabular form for statistical examination. The same test time, equipment, and environment will be used to guarantee the reliability/validity of collected data.

F. Statistical Technique

The collected data will be analyzed using the following statistical methods: The paired t-test will be performed to compare pre- and post-test scores for the subjects. The significance level will be set at 0.05. Statistical analysis will be performed to determine if the differences observed are statistically significant.

G. Training Schedule

The plyometric training program will be supervised by the researcher for a duration of five (5) weeks, attended three to four times per week. Every session lasts roughly 35-45min with warm-up and cool-down. Implementation of a gradually increased training load in order to ensure progressive development and injury prevention.

TABLE I
FIVE-WEEK PLYOMETRIC TRAINING
PROGRAMME

Week	Exercises	Sets × Repetitions	Frequency	Duration
1	Skipping, Jump Squats, Ankle Hops	2 × 10	3 Days/Week	35 Minutes
2	Box Jumps, Tuck Jumps, Squat Jumps	3 × 10	3 Days/Week	40 Minutes
3	Bounding, Hurdle Hops, Lateral Jumps	3 × 12	4 Days/Week	40 Minutes
4	Depth Jumps, Single-Leg Hops, Split Jumps	3 × 12	4 Days/Week	45 Minutes
5	Advanced Bounding, Multiple Box Jumps, Power Hops	4 × 12	4 Days/Week	45 Minutes

H. Structure of Each Training Session

Each training session will be divided into three phases:

Warm-Up (10 Minutes)

- Light jogging
- Dynamic stretching
- Mobility exercises
- Skipping

Main Plyometric Training (20–25 Minutes)

- Performance of selected plyometric exercises
- Adequate rest between sets (60–90 seconds)
- Emphasis on proper technique and safety

Cool-Down (5–10 Minutes)

- Light walking
- Static stretching
- Relaxation exercises

III. ANALYSIS OF DATA & RESULTS

TABLE II
DESCRIPTIVE STATISTICS OF VERTICAL
JUMP PERFORMANCE BEFORE AND
AFTER PLYOMETRIC TRAINING

Variable	Vertical Jump (Pre-test)	Vertical Jump (Post-test)
Mean	46.4	52.95
Median	46	53
SD	1.5	1.79
SE Mean	0.34	0.4
Minimum	44	50
Maximum	49	56
Skewness	0.16	-0.1
Kurtosis	-0.79	-1.03

Table II shows the descriptive statistics regarding vertical jump performance recorded before and after plyometric training in male athletes. Pre-training vertical jump height mean was 46.40 (SD = 1.50) cm which indicates moderate jumping performance with low variability. Following training, this increased to 52.95 cm (SD = 1.79), an improvement of 6.55 cm. The median was 53.00 cm (range 6.00 cm), showing uniformly improved performance across subjects. Post-training skewness of -0.10 and a kurtosis of -1.03 indicate mild negative skewness and a platykurtic distribution, reflecting normality and satisfying parametric analyses assumptions for normality. Ultimately, these statistics imply that plyometric training greatly develops a player's vertical jump performance due to increased utilization of explosive leg power and neuromuscular coupling.

TABLE III
DESCRIPTIVE & INFERENTIAL
STATISTICS OF VERTICAL JUMP
PERFORMANCE BEFORE & AFTER
PLYOMETRIC TRAINING

Variable	Vertical Jump Performance	Vertical Jump Performance
Test	Pre-test	Post-test
Mean (cm)	46.4	52.95
SD	1.5	1.79

Variable	Vertical Jump Performance	Vertical Jump Performance
Mean Difference	6.55	-
SD of Difference	0.51	-
SE Difference	0.11	-
df	19	-
t-value	57.39	-
p-value	.000*	-

Table III Descriptive statistics and paired samples t test of plyometric training effects on vertical jump Baseline characteristics of participants The mean vertical jump height (VJH) in females and males before the BPC therapy was 46.40 cm (SD =1.50). Light grey, filled diamonds with solid line: group effect on quality movements of 6.55 cm (SD=0.51). With a standard error of the mean difference = 0.11, it represents an extremely precise estimate of improvement.

The t-test for paired samples produced a $t(19) = 57.39$, $p < .001$, evidence against the null hypothesis. This can be written up in APA style for these results: A paired-samples t-test revealed a significant improvement between scores on the plyometric training, $t(19) = 57.39$, $p < .001$, emphasizing how this training improves explosive leg power.

This improvement is mediated by enhanced physiological adaptations secondary to plyometric training, including neuromuscular coordination and the utilization of elastic energy. That's a whopping 6.55 cm improvement in jump height, which is exactly what we want for sports that demand explosive lower-limb power like kabaddi, volleyball & basketball [4]. Plyometric training has consistently been shown to be an effective method of improving lower-body power output, and these consistent improvements across both the experimental and control groups simply reinforce plyometrics as a common practice when developing athletic performance.

IV. DISCUSSION

The purpose of the present study was to find out the effect of plyometric training on vertical jump performance of male sports trainees in Guru Kashi Defense Academy, Bathinda, Punjab. A 6.55 cm increase in jump height (mean jump height from 46.40 cm to 52.95 cm, $P < .001$) was observed after a five-week intervention period for vertical jump in each group combined with resistance training. The consistency of the improvement was highlighted by low pre- and post-training standard deviations. For plyometric training, the bias estimate was 18 cm (95% CI: 15 to 21; $p < 0.001$), indicating that plyometric training generates a large positive effect on improving vertical jump performance.

It is likely that the improvements could be attributed to the physiological adaptations required in the stretch-shortening cycle, which result in a greater capacity for elastic energy storage and muscle release. The increase in neuromuscular coordination due to dynamic movements such as jump squats and box jumps was particularly significant because it resulted in greater player muscle utilization and better neural integration, both of which help you achieve a high jump. These findings are similar to those of Martinez-Garcia et al. and Kelley et al. (Article 7, which compared vertical jump parameters of competitive athletes after an eight-week plyometric training block and observed clinically meaningful improvements. The association further supports the literature suggesting plyometric training may improve muscle-tendon functionality and explosive power. Similarly, Ferrer et al. General improvements. Due to differences in research modality [3], they had greater positive results from lower-body power training when combined with regular plyometric training compared to novice collegiate athletes only on the plyometric training. Although our work only examined plyometrics specifically, the results support their efficacy in power development.

In a similar study conducted by Rahman et al. In agreement with these findings, [10] observed clinically important improvements in exploratory strength and agility within a cohort of youth athletes after a six-week plyometric training protocol at Guru Kashi Defense Academy. Furthermore, Williams et al. [14] reported neuromuscular adjustments directly associated with improvement in vertical jump height, similar to our results. Singh and Sharma [12] is another example that also reported a beneficial effect on vertical jump in Indian collegiate athletes after an 8-week plyometric exercise program, supporting the implementation of plyometric training among sports programs in India. Our finding among male Defense service aspirants from Punjab is consistent with the conclusions of a meta-analysis by Markovic [6] observing plyometric training beneficial across varied athletic populations.

The measured increase of 6.55 cm in vertex jump clearly reflects performance enhancement in lower-body explosive power-a determining factor for athletic success and a necessary component of many Defense-related physical activities. A possible reason for the success of the training protocol is not based on either volume or intensity alone, but rather on its progressive overload principle, such that both are incrementally increased throughout the regimen. These results indicate that plyometric training may be an effective method for improving vertical jump height and explosive leg strength in male athletes, suggesting its use in conditioning programs for athletes and Defense aspirants.

V. CONCLUSION

Research carried out on thirty male players of age 18–22 years at Guru Kashi Defense Academy, Bathinda, Punjab tested the impact of a 5-week plyometric training program on vertical jump height. Performance improvements were particularly large in vertical jump scores, with means of 46.40 cm (SD ± 11.6) before testing and 52.95 cm (± 10.3) immediately after post-testing, a change of +6.55

cm. This again was statistically significant and practically meaningful based on a paired-samples t-test ($t = 57.39$, $p < .001$). The bulk of these improvements may come from peak forces produced through the stretch-shortening cycle and/or potential neuromuscular changes. The results are consistent with previous studies and additionally support earlier research that suggested plyometric training is beneficial for physical performance [40]. The study concluded this programming could be a relatively low time-investment 5-week intervention that elicits potentially significant increases in explosive leg power, and should therefore be considered for incorporation into existing conditioning programs at Defense academies. The null hypothesis was accepted for both vertical jump performance and explosive strength, supporting the hypothesis that plyometric training improves both physical capabilities. In conclusion, plyometric training is a functional workout to improve the athletic performance of sports persons and Defense aspirants.

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Self-Esteem in Physical Education and Non-Physical Education Students: A Multidimensional Comparative Study

¹ Ms. Megha Sharma, ² Dr. Ravi Kumar

¹Department of Physical Education, Guru Kashi University, Bathinda.

²Associate Professor, Department of Physical Education, Guru Kashi University, Bathinda.

Email Id: ¹meghasharm789@gmail.com, ² ravikumar.gahalawat@gmail.com

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Abstract— Self-esteem is a multidimensional psychological construct that is well-established and linked to mental health, academic persistence, and social functioning. Studies known to improve individuals' self-esteem are important, but only a few have compared students enrolled in actual Physical Education (PE) programs with those in non-physical education programs in India, particularly in the higher education sector. In this study, we compared our global and domain-specific self-esteem (athletic competence, physical appearance, social acceptance, and scholastic competence) between PE and non-PE postgraduate students. We also looked for differences and interaction effects by gender. A quantitative, cross-sectional comparative design was employed. Sixty postgraduate students from Rajasthan University (30 PE, 30 non-PE; 15 males and 15 females per group; aged 18–25 years) were selected via purposive sampling. Global self-esteem was measured using the Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965), and domain-specific self-esteem was measured using four subscales of Harter's Self-Perception Profile for Adolescents (SPPA; Harter, 2012). Data were analysed using independent samples t-tests and two-way ANOVA at $\alpha = 0.05$. PE students scored significantly higher on global self-esteem ($M = 25.80$ vs. 23.60 ; $t = 4.21$, $p < 0.001$, $d = 1.09$), athletic competence ($d = 3.45$), physical appearance ($d = 1.42$), and social acceptance ($d = 1.25$). Non-PE students scored significantly higher on scholastic competence ($M = 21.50$ vs. 13.70 ; $d = 5.02$). Male students had higher

global self-esteem than females ($M = 26.00$ vs. 23.40 ; $d = 1.39$). Two-way ANOVA confirmed significant main effects for both specialisation ($\eta^2 = 0.25$) and gender ($\eta^2 = 0.32$), but no significant interaction ($F = 0.32$, $p = 0.574$). Six of seven hypotheses were supported. Findings confirm the domain-specific nature of self-esteem and underscore the value of structured physical education for psychosocial development in higher education.

Keywords: Self-Esteem; Physical Education; Rosenberg Self-Esteem Scale; Athletic Competence; Scholastic Competence; Gender Differences; Two-Way ANOVA; Indian Higher Education.

I. INTRODUCTION

Among the most widely studied constructs in educational psychology are self-esteem and self-efficacy. It refers to an individual's overall subjective evaluation of their own worth. It is not simply a single feeling or sensation; it operates across different areas of life at the same time. The general view was captured by Rosenberg in 1965 and then extended into various domains by Harter in 2012. The main domains are scholastic competence, social acceptance, athletic competence, physical appearance, and behavioural conduct. The critical insight from this multidimensional framework is that people can feel highly capable with respect to one thing but not with respect to another, and that the things they value most are what they derive their overall worth from.

This domain-specific structure makes academic specialization a potentially powerful variable in self-esteem research. Students doing Physical Education courses spend their days learning about, training for, competing in and getting feedback on physical performance. Constant testing and reinforcement of self-worth in athletic and appearance domains. By contrast, humanities, social sciences, sciences, and commerce students anchor their self-evaluations mainly to cognitive performance – grades, analytical ability, and academic recognition. Physical activity is usually optional, unmarked, and socially irrelevant in their academic programme.

The connection between physical activity and self-esteem is well established. According to meta-analysis, there is a positive relationship between exercise participation and both global and physical esteem [1][2][3]. Despite that, most such research treats physical activity as a behavior rather than as a formal academic program. The academic aspect of PE is more rigorous, more evaluative, and more socialized than the recreational aspect. Public training, formal competitions, and constant assessment of skill and fitness create a qualitatively different self-esteem environment for PE students.

However, the literature does not all agree. Some (but not all) studies have found higher physical and global self-esteem among PE students [4],[5], while another study did not find any difference after controlling for prior activity or personality [6]. Gender makes it more complicated because females report less physical appearance satisfaction and lower global self-esteem than males consistently, and the gap widens during adolescence [7]. How PE enrolment differentially buffers versus exacerbates this gender gap, especially in Indian higher education systems, remains largely unexplored.

To address these gaps, the present study is designed on a focused comparative basis with 60 postgraduate students from Rajasthan University, divided equally by gender and by PE and non-PE programs. Measuring global self-esteem, in addition to four

dimension-specific self-esteem measures, offers a comprehensive picture of how academic specialization can shape students' self-perceptions, where each group excels, and whether these effects operate independently of gender.

II. REVIEW OF RELATED LITERATURE

Gonzalez Orozco [8] through an analysis of 450 adolescents found significant positive correlations of the frequency of physical activity with self-esteem ($r = 0.42$) and satisfaction with body image ($r = 0.38$).

According to research, body image partially accounted for the effect of physical activity on self-esteem, and female participants consistently reported lower self-esteem and greater body image dissatisfaction than males.

A longitudinal study of 2,066 children [9] revealed that sport type substantially shapes domain-specific self-esteem. Team sport participants demonstrated higher social acceptance and athletic competence than individual sport participants. Students in aesthetic sports (gymnastics, dance) showed lower athletic competence and social acceptance than non-aesthetic sport participants, reinforcing that the specific context of physical activity shapes self-perceptions, not merely its presence.

Gorospe and Ferrer [10] directly compared 161 college students using the Physical Self-Description Questionnaire, finding that PE majors scored significantly higher in sport competence, strength, endurance, and overall global physical self-concept. This study is most directly analogous to the present investigation and provided the basis for our primary hypotheses.

Research conducted by Sharma and Patel [11] on PE and non-PE university students in India revealed that PE students scored significantly higher on social acceptance and the quality of peer relationships. A mediation analysis indicated that social acceptance mediated the relationship between academic

specialization and self-esteem (indirect effect = 0.14, 95% CI = 0.06–0.22). This finding suggests that the team-based setting of PE programs facilitates peer networks that enhance self-worth.

Martinez and Thompson [12] investigated the differences between female sports science (n = 120) and humanities students (n = 120), where they found that the former reported significantly higher body image satisfaction (d = 1.72) and global self-esteem (d = 0.95). Notably, some sports science students reported experiencing body dissatisfaction concerning certain body parts. This suggests that intensive training does not completely insulate athletes from the body-related pressures instigated by the sociocultural context.

Ahmed and Khan [13] provide a useful counterpoint since their Pakistani samples found that PE students scored lower than non-PE students (M = 25.4 vs. 28.7) on the global RSES. Only on sport-specific measures did the PE students score higher. This implies that in cultural settings where academic performance is a more socially valued quality, global self-esteem may not be automatically favorable to the physically active person.

The meta-analysis by Anderson and Taylor [14], which synthesized 48 studies (N = 28,476), found that athletes had significantly higher global self-esteem than non-athletes (g = 0.41) with the largest effects for adolescents (g = 0.52), females (g = 0.48), and team sport participants (g = 0.49). The greater impact for females is especially important: structured physical activity may be particularly helpful for female students who usually start from a lower self-esteem baseline. Ekland et al. [1] and Spence et al. [2] provided systematic support which shows that exercises effects are strongest in mastery-oriented, non-competitive settings of more than 12 weeks. Combining both studies, it is interpreted that students subjected to physical education will have higher physical and social self-esteem. However, it was observed that students, who are not subjected to

this discipline, will lead to higher scholastic competence.

III. OBJECTIVES AND HYPOTHESES

The study pursued seven objectives: (1) to compare global self-esteem between PE and non-PE students; (2–5) to compare athletic competence, physical appearance, social acceptance, and scholastic competence between groups; (6) to compare self-esteem between male and female students; and (7) to examine the interaction effect of academic specialisation and gender on global self-esteem.

Seven hypotheses were formulated. H₁: PE students have higher global self-esteem. H₂: PE students have higher athletic competence. H₃: PE students have higher physical appearance self-esteem. H₄: PE students have higher social acceptance. H₅: Non-PE students have higher scholastic competence. H₆: Male students have higher global self-esteem than females. H₇: There is a significant interaction between specialization and gender on global self-esteem.

IV. METHODOLOGY

4.1 Design and Participants

A quantitative, cross-sectional comparative design (ex-post facto) was employed. Sixty postgraduate students from Rajasthan University were selected through purposive sampling: 30 PE students (M.P.E.d programme) and 30 non-PE students (M.A./M.Sc. programmes). Each group comprised 15 males and 15 females, aged 18–25 years. Purposive sampling ensured balanced representation across groups and gender. Students with self-reported diagnosed mental health conditions or those outside the target age range were excluded. All participants provided written informed consent prior to data collection.

Table 1: Participant Characteristics by Group and Gender.

Group	Male (n)	Female (n)	Total (n)	Age Range	Programme

PE Students	15	15	30	18–25 years	M.P.E.d
Non-PE Students	15	15	30	18–25 years	M.A./M.Sc. (various)
Total	30	30	60	18–25 years	—

4.2 Instruments

The Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965) is a ten-item, four-point Likert-scale measure (a 3 = Strongly Agree; a 0 = Strongly Disagree). The aggregate scores can range from 0 to 30. The ideal range is between 15 and 25, as anything below 15 indicates low self-esteem and anything above 25 indicates high self-esteem. The test-retest reliability coefficient was good ($r = 0.85$), as was the internal consistency ($\alpha = 0.88$).

The Self-Perception Profile for Adolescents (SPPA; Harter, 1988, 2012) comprised four subscales (6 items each): Athletic Competence, Physical Appearance, Social Acceptance, and Scholastic Competence.

The alternative-response format of items is structured so that one indicates low competence and four indicates high competence, and it aims to minimize social desirability. The internal consistency of the subscales ranges from $\alpha = 0.75$ to 0.85.

4.3 Procedure and Statistical Analysis

With the institution's permission and informed consent, the questionnaires were administered in classrooms over two weeks under the researcher's supervision. After screening the completed forms, we scored them as detailed in the respective manuals and entered the data into SPSS 26.0. All groups were characterized with descriptive statistics. Using independent-samples t-tests, comparisons were made between the PE and non-PE groups for each of the five self-esteem variables, and between males and females for global self-esteem. Overall self-esteem was analyzed by gender and specialization using a two-way ANOVA. G*Power software was

used to conduct power analyses for the significant effects. All test interpretations were done at level 0.05.

V. RESULTS AND DISCUSSION

5.1 Descriptive Statistics

Table 2: Descriptive Statistics for All Variables by Group (N = 60)

Variable	PE Group M (SD)	Non-PE Group M (SD)	Min–Max (PE)	Min–Max (Non-PE)
Global Self-Esteem	25.80 (2.10)	23.60 (2.00)	22–30	20–27
Athletic Competence	19.50 (2.23)	12.80 (1.65)	16–24	10–16
Physical Appearance	17.80 (2.20)	14.90 (1.85)	14–22	12–18
Social Acceptance	19.40 (1.77)	17.30 (1.60)	17–23	15–20
Scholastic Competence	13.70 (1.41)	21.50 (1.65)	11–16	19–24

The descriptive pattern is striking before any inferential test is applied. PE students consistently outperform non-PE students on all physical and social domains, while non-PE students lead scholastic competence by nearly 8 points. This profile is exactly what Harter's (2012) domain-specificity principle would predict: people build self-perceptions most powerfully within the domains they inhabit and practice daily.

5.2 Group Comparisons: PE vs. Non-PE

Table 3: Independent t-test Results — PE vs. Non-PE Students

Variable	Mean Diff.	t-value	df	p-value	Cohen's d	Effect	Hypothesis
Global Self-Esteem	+2.20 (PE↑)	4.21	58	<0.001	1.09	Large	H ₁ ✓ Accepted
Athletic Competence	+6.70 (PE↑)	13.25	58	<0.001	3.45	Very Large	H ₁ ✓ Accepted
Physical Appearance	+2.90 (PE↑)	5.50	58	<0.001	1.42	Large	H ₁ ✓ Accepted
Social Acceptance	+2.10 (PE↑)	4.86	58	<0.001	1.25	Large	H ₁ ✓ Accepted
Scholastic Competence	–7.80 (Non-PE↑)	19.38	58	<0.001	5.02	Very Large	H ₁ ✓ Accepted

Each of the five comparisons was statistically significant at $p < 0.001$ and had large to very large effect sizes, confirming that these are real-world differences in self-perception, and not statistical artifacts.

The advantage of athletic competence for PE students ($d = 3.45$) is among the largest effects found in similar literature. Students who are in PE have their academic lives spent developing and formally assessed on physical skills. The positive muscle memory associated with daily training, coaching feedback and competitive performance creates a powerful reinforcement loop that raises the athletic self-perceptions of athletes well above those of students who rarely experience formal evaluation of physical skills. This finding corresponds directly to Gorospe and Ferrer [10].

The physical appearance effect ($d = 1.42$) is in line with Martinez and Thompson [12] and Fox [15], whose findings showed that physical self-concept partially mediated the activity-self-esteem relationship, accounting for 42% of variance. Regularly participating in structured training appears to be associated with more positive body image perceptions, but cross-sectional data do not allow causation to be inferred.

The PE students also showed more social acceptance, meaningfully compared to asthmatic students ($d = 1.25$) of Sharma and Patel [11]. The cooperation and collective character of PE programs, shared training schedules, team travel, and common goals, give rise to stronger peer networks than the more individualistic academic environments of non-PE programs.

The scholastic competence reversal ($d = 5.02$) is the most dramatic finding. Non-PE students score nearly 8 points higher on academic self-perception. The effect size of 5.02 is nearly twice that of any other comparison in the study. This makes intuitive sense: non-PE students' entire academic experience revolves around intellectual performance and cognitive achievement. The magnitude of this gap

echoes Ahmed and Khan [13] and raises practical concerns about the “dumb jock” stereotype [16] — though, again, cross-sectional data cannot establish whether PE enrolment leads to lower academic self-perception or whether students with lower academic self-concept are more likely to self-select into PE.

Critically, PE students' higher global self-esteem ($d = 1.09$) despite substantially lower scholastic competence supports Harter's (2012) model that global self-worth is driven by success in personally valued domains. Physical competence, not academic performance, is the primary currency of self-worth for PE students, and they are accumulating it daily.

5.3 Gender Differences

Table 4: Gender Comparisons on Global Self-Esteem Within and Across Groups

Context	Male M (SD)	Female M (SD)	t-value	p-value	Cohen's d
PE Group only	27.10 (1.70)	24.50 (1.68)	4.21	<0.001	Large
Non-PE Group only	24.90 (1.35)	22.30 (1.38)	5.21	<0.001	Large
Both Groups Combined	26.00 (1.83)	23.40 (1.88)	5.49	<0.001	1.39

Male students scored significantly higher on global self-esteem than female students in both groups and overall ($d = 1.39$), supporting H₆. This is consistent with the well-established literature on gender and self-esteem [7, 18], driven largely by physical appearance dissatisfaction among females. What is particularly notable here is that PE enrolment does not close the gender gap. Female PE students score higher than female non-PE students, but the gap between males and females remains essentially the same within each programme. Whatever forces suppress female relative self-esteem operate at a level that academic programme alone cannot alter. Within the PE group, the one domain where no gender difference emerged was scholastic competence ($t = 0.39$, $p = 0.698$). This is actually encouraging: in academic self-perception, male and female PE students see themselves as equally capable, even if both perceive themselves as less

academically able than their non-PE peers. This gender-neutral academic self-perception within PE programmes may be worth building upon through targeted academic confidence interventions.

5.4 Interaction Effect: Two-Way ANOVA

Table 5: Two-Way ANOVA Summary — Global Self-Esteem (N = 60)

Source	SS	df	MS	F-value	p-value	Partial η^2	Result
Specialisation (PE vs. Non-PE)	72.600	1	72.60	19.25	<0.001	0.25	Significant
Gender (Male vs. Female)	101.40	1	101.40	26.88	<0.001	0.32	Significant
Specialisation $\times$ Gender	1.20	1	1.20	0.32	0.574	0.01	Not Significant
Error	211.20	56	3.77	—	—	—	—
Total	386.40	59	—	—	—	—	—

Table 6: Mean Global Self-Esteem Scores by Group and Gender

Specialisation	Male M (SD)	Female M (SD)	Group Total M (SD)
PE Students	27.10 (1.70)	24.50 (1.68)	25.80 (2.10)
Non-PE Students	24.90 (1.35)	22.30 (1.38)	23.60 (2.00)
Gender Total	26.00 (1.83)	23.40 (1.88)	24.70 (2.55)

Both of the main effects proved significant and practically large. Specifically, specialization ($\eta^2 = 0.25$) accounts for 25 percent of variance in global self-esteem and gender ($\eta^2 = 0.32$) accounts for 32 percent. Such differences are far from trivial; they indicate real differences in the way students experience their own sense of worth across academic and gender categories.

The H_7 hypothesis was rejected since the interaction term was not significant ($F = 0.32$, $p = 0.574$, $\eta^2 = 0.01$). This is an important empirical finding: the self-esteem advantage of PE versus non-PE is equally present for males and females. Participation

in PE boosts self-esteem by a similar amount for all genders. In the same way, the male edge over females holds across academic specialisation. These effects add to each other, rather than multiplying.

This not significant interaction sends a simple message for intervention design. That is, initiatives to enhance self-esteem through physical education will likely be equally beneficial for boys and girls. At this level, there is no evidence that gender determines who benefits most from enrolment in PE.

5.5 Hypothesis Testing Summary

Table 7: Summary of Hypothesis Testing Results

Hyp.	Statement	Key Statistic	Outcome
H_1	PE students have higher global self-esteem	$t = 4.21$, $d = 1.09$, $p < 0.001$	Accepted ✓
H_2	PE students have higher athletic competence	$t = 13.25$, $d = 3.45$, $p < 0.001$	Accepted ✓
H_3	PE students have higher physical appearance self-esteem	$t = 5.50$, $d = 1.42$, $p < 0.001$	Accepted ✓
H_4	PE students have higher social acceptance	$t = 4.86$, $d = 1.25$, $p < 0.001$	Accepted ✓
H_5	Non-PE students have higher scholastic competence	$t = 19.38$, $d = 5.02$, $p < 0.001$	Accepted ✓
H_6	Male students have higher global self-esteem than females	$t = 5.49$, $d = 1.39$, $p < 0.001$	Accepted ✓
H_7	Significant interaction: specialisation $\times$ gender	$F = 0.32$, $\eta^2 = 0.01$, $p = 0.574$	Rejected ✗

VI. CONCLUSION

According to this study on academic specialization, it offers a clear and empirically derived portrait of self-esteem. Students of Physical Education have a significant edge in global self-esteem and in all individual physical, athletic, and social domain tested. The consistent exposure to organized physical training, peer cooperation and construction, along with continuous feedback from numerous performances, develops a sturdy physical self that enhances the overall worth of the child. Non-PE

students have a different evaluative world, developing self-worth mainly through intellectual achievement, and their scores for scholastic competence reflect this with remarkable clarity.

Neither group believes in itself. The PE students' low self-perception of their academic ability is a real vulnerability that, if left unchecked, may limit their academic confidence and career ambition beyond sport. The non-PE students are lower in physical and social self-esteem, which may be a real deficit in well-being that extra recreation could not fix. One can learn something real from each other's domain.

The constant gender gap—men outperforming women in all programs indicates that curriculum change is not enough in itself. The cultural and psychological forces that diminish women's relative self-esteem cannot be mitigated by affiliation with an academic program. It is necessary to implement the gender-sensitive intervention alongside the curriculum-level change, but only within specific domains.

The non-significant interaction effect sends a policy relevant and optimistic message: structured physical education benefits all students equally, regardless of gender. Expanding PE across other non-PE programmes is likely to yield self-esteem benefits for females similar to those for males.

VII. PRACTICAL RECOMMENDATIONS

To university administrators and policy makers: The evidence supports implementing a structured, mastery-oriented physical activity programme across all postgraduate programmes. Physical education not only promotes health but also improves self-esteem, social acceptance and body image as a psychosocial intervention. Even a little bit of non-competitive exercise skills training is likely to provide substantial psychosocial benefits for non-PE students currently experiencing stunted physical and social self-perceptions.

Physical Education (PE) instructors as well as Coaches: The marked academic skills deficiency among PE students requires direct instructional strategies. PE teachers must actively enhance students' assessments of their academic self through theoretical courses, research assignments, and explicit discussions of sport science. The aim is to enhance self-concept rather than undermine the physical identity of PE students whose self-esteem is entirely reliant on performance.

For guidance counselors and psychologists: The persistent gap in self-esteem between the sexes presents a challenge for those working with students in academic settings. Gender-sensitive programs are needed to promote body image resilience, assertive self-promotion, and diverse competencies. Interventions must not only use global measures of self-esteem but also domain-specific self-esteem measures to help students. For example, a female non-PE student with low athletic self-esteem must have a different educational program from a female PE student with low academic self-esteem.

Researchers in the future will have to use longitudinal designs to ascertain whether self-esteem differences exist before enrolment in the program or emerge as a result of enrolment. Generalizability beyond the University of Rajasthan can be improved with multi-institution, larger samples. Using qualitative interviews in mixed-methods approaches would enrich understanding of how studied students build and narrate their self-worth across diverse contexts.

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