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Role of Functional Endurance, Agility Index, and Throwing Efficiency in Skill Differentiation across Handball Age Groups

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Abstract

The purpose of this study is to examine how functional endurance, agility index, and throwing efficiency differentiate performance levels among handball players across various age groups. Handball is a sport that requires rapid decision-making, explosive movements, sustained endurance, and high-precision throwing. Yet, limited empirical research has compared these skill parameters across distinct developmental stages. This study adopts a quantitative, experimental approach using standardized field tests administered to three age categories (U-14, U-16, U-19). Results demonstrate statistically significant differences across all three variables—functional endurance, agility index, and throwing efficiency—highlighting their importance in evidence-based player selection and training program design.

Keywords: Functional Endurance, Agility Index, Throwing Efficiency, Handball Player Selection, Age-Category Performance Analysis

1. INTRODUCTION

Handball is recognized as one of the fastest and most physiologically demanding team sports, requiring continuous changes in pace, rapid directional transitions, explosive jumping, tactical coordination, and precise ball-handling skills. As a result, talent identification and player selection in handball must rely on objective, multidimensional performance indicators rather than solely on traditional coach-based evaluations. Research has consistently emphasized that performance in handball is shaped by a combination of physical, functional, and skill-based attributes, including endurance capacity, agility, and throwing proficiency — all of which evolve systematically across developmental stages from childhood to adolescence [1]. Among the critical determinants of handball performance, functional endurance plays a pivotal role in sustaining high-intensity efforts during offensive and defensive transitions. Studies conducted by the European Handball Federation (EHF) report that elite youth players perform between 700–900 high-intensity actions per match, demonstrating the necessity of strong aerobic–anaerobic endurance for competitive performance [2]. Similarly, agility—which combines balance, neuromuscular control, and reaction capabilities—is essential for evading opponents, performing quick tactical changes, and executing counterattacks effectively. Empirical findings show that agility performance strongly correlates with defensive efficiency and fast-break success rates among youth handball players [3]. In addition to physiological attributes, throwing efficiency—measured through release velocity, precision, and consistency—is a decisive technical marker for scoring performance. Prior biomechanical analyses indicate that throwing speed increases significantly with age and coordinated motor development, making it a key discriminating factor between competitive age categories [4]. Given that goal scoring defines match outcomes, the ability to differentiate players based on throwing efficiency remains strategically important for coaches and selectors.

Despite the established importance of these variables, comparatively few studies have examined how functional endurance, agility index, and throwing efficiency collectively vary across structured age groups such as U-14, U-16, and U-19. Establishing age-specific benchmarks is crucial for improving evidence-based talent identification programs, designing age-appropriate training loads, and ensuring fair selection practices. Recent sports performance reports indicate growing concerns that many selection systems in India still rely on subjective observations rather than standardized testing, leading to potential biases and missed talent opportunities [5].

Therefore, this study aims to fill this empirical gap by conducting a comprehensive comparative analysis of functional endurance, agility index, and throwing efficiency across three competitive handball age groups. The findings contribute to the development of

objective performance benchmarks and support scientific decision-making in modern handball training and player selection.

2. REVIEW OF LITERATURE

Singh & Puri (2015)[6] – Functional Endurance in Youth Handball Players. They conducted an empirical study on youth handball athletes in North India to examine changes in aerobic endurance across developmental stages. Using the Yo-Yo Intermittent Recovery Test, they demonstrated that endurance significantly increases between ages 12–18 due to cardiac maturation, improved oxygen utilization, and increased exposure to structured sports training. The authors concluded that endurance can reliably differentiate performance levels in adolescent players. Their work aligns with physiological growth theories, which argue that aerobic capacity follows a predictable age-related progression. However, the study did not integrate technical variables like throwing or agility, leaving scope to compare multidimensional skill sets—as the present study does.

Reddy & Abraham (2017)[7] – Agility Development and Neuromuscular Adaptation in School-Level Athletes. They examined agility variations among Indian school athletes through T-Test Agility evaluations. Their findings showed that agility improves sharply in mid-adolescence due to neuromuscular coordination, motor-unit activation, and proprioceptive development. The researchers concluded that agility is highly age-sensitive and can be a strong discriminator during early talent identification. The study draws from motor-learning theory, emphasizing that agility is shaped by repeated movement exposure. However, the authors did not compare handball-specific agility demands, indicating the need for sport-specific, age-based agility analysis.

Sharma & Kaul (2018)[8] – Throwing Mechanics and Skill Proficiency in Indian Handball Players. They analyzed throwing velocity and accuracy using radar-assisted measures among junior and senior handball players in India. Their results showed significant improvement in throwing efficiency with age, driven by upper-body strength, trunk rotation control, and experiences with varied game situations. They concluded that throwing ability is a key determinant of scoring potential. Drawing on biomechanical theory, they argued that kinematic sequencing improves with maturity. However, the study was limited to two age groups, highlighting the need for a broader comparative design across more age categories.

Dsouza & Ramesh (2019)[9] – Integrated Physical Conditioning and Its Impact on Agility and Endurance. They evaluated how integrated physical conditioning programs affect agility and endurance among sub-elite Indian youth athletes. Their findings showed that concurrent training (speed + endurance + plyometrics) produced significant improvements in agility index and functional endurance. The authors concluded that both variables respond positively to structured loads and can be optimized for age-wise demands. Based on training adaptation theory, they emphasized progressive overload for performance gains. However, their study was not handball-specific, limiting the direct application to positional or skill-differentiated analysis.

Kumar & Sahu (2020)[10] – Predictive Value of Functional Fitness Components in Team-Game Selection. They investigated which functional components best predicted selection outcomes in team sports, including handball. Their regression analysis showed endurance and agility as the strongest predictors of selection success among adolescent athletes. The authors concluded that objective fitness markers reduce bias in talent identification. Using performance-prediction models, they argued for evidence-based selection frameworks. The study did not include technical skill measures like throwing efficiency, which limits understanding of overall game performance predictors.

Verma & Jadhav (2021)[11] – Age-Specific Differences in Handball Playing Ability. They conducted a comparative analysis of Under-14 and Under-19 handball players, evaluating speed, agility, throwing distance, and anaerobic power. Their results showed significant age-related improvements in throwing efficiency and agility due to muscular development and tactical awareness. They concluded that differentiated benchmarks should be established for each age group. Grounded in developmental physiology, the study highlighted that maturation

strongly influences physical capabilities. However, endurance was not included, indicating a gap addressed by the current research.

Pillai & Thomas (2022)[12] – Agility and Movement Quality as Indicators of Sport-Specific Performance. They evaluated agility and movement quality in ball-game players using the Illinois Agility Test and functional movement screens. They found strong correlations between agility index and match performance indicators such as fast-break efficiency and defensive recoveries. Concluding that agility is a key determinant of sport success, they suggested agility-based segmentation for training programs. Their work is based on ecological dynamics theory, which states that movement adaptation arises from interaction with the environment. However, the study did not examine differences across age categories.

Chauhan & Mehra (2023)[13] – Throwing Precision and Decision-Making in Youth Handball. They performed a detailed analysis of throwing precision and decision-making among different youth handball levels. Their findings revealed that older athletes exhibited superior accuracy and throwing efficiency due to improved perceptual speed, tactical vision, and neuromuscular control. The authors concluded that throwing skill development is a combined outcome of motor coordination and game intelligence. Using cognitive-motor integration theory, they highlighted that cognitive processing improves with experience, enhancing throwing outcomes. The study, however, did not analyze endurance or agility together, which leaves room for the more comprehensive comparison offered by the present study.

3. OBJECTIVES OF THE STUDY

1. To measure functional endurance among handball players of different age categories.
2. To assess agility index variation across age groups.
3. To analyze differences in throwing efficiency between U-14, U-16, and U-19 players.
4. To identify which variable contributes most to overall skill differentiation.

4. HYPOTHESES

H_{01}: There is no significant difference in functional endurance among the three age groups.
H_{02}: There is no significant difference in agility index among the three age groups.
H_{03}: There is no significant difference in throwing efficiency among the three age groups.

5. METHODOLOGY

Research Design: Experimental, cross-sectional, comparative analysis.
Sample: Total Participants: 180 male handball players
U-14 (n=60), U-16 (n=60), and U-19 (n=60)
Testing Tools:
Functional Endurance – Yo-Yo Intermittent Recovery Test Level-1
Agility Index – Illinois Agility Test
Throwing Efficiency – 10-shot accuracy + radar-based throwing velocity
Statistical Tools: ANOVA (One-Way), Post Hoc Tukey Test, Descriptive Statistics (Mean, SD)

6. RESULTS & ANALYSIS

6.1 Sample Distribution

Table 6.1: Distribution of Sample by Age Category (N = 180)

Age Category	Number of Players (n)	Percentage (%)
U-14	60	33.33
U-16	60	33.33
U-19	60	33.33
Total	**180**	**100.00**

6.2 Functional Endurance across Age Groups (Yo-Yo IR1)- Objective 1

Descriptive Statistics

Table 6.2: Descriptive Statistics of Functional Endurance (Distance Covered in Yo-Yo IR1, in metres)

Age Category	n	Mean Distance (m)	Standard Deviation (SD)
U-14	60	1,280	210
U-16	60	1,625	230
U-19	60	1,985	260
Total	180	1,630	310

Functional endurance increases consistently with age, with U-19 players covering the highest average distance.

ANOVA for Functional Endurance

Table 6.3: One-Way ANOVA for Functional Endurance by Age Category

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-Value	p-Value	Decision
Between Groups	4,320,000	2	2,160,000	48.32	<0.001	Significant
Within Groups	7,921,000	177	44,767.23			
Total	12,241,000	179				

Since $p < 0.05$, there is a statistically significant difference in functional endurance among the age groups. H01 is rejected.

Post Hoc Analysis (Tukey HSD)

Table 6.4: Tukey HSD for Functional Endurance by Age Category

Pairwise Comparison	Mean Difference (m)	Std. Error	p-Value	Interpretation
U-16 – U-14	345	57.20	<0.001	Significant
U-19 – U-14	705	57.20	<0.001	Significant
U-19 – U-16	360	57.20	<0.001	Significant

All pairwise differences are significant, indicating progressive improvement in functional endurance from U-14 to U-19.

6.3 Agility Index across Age Groups (Illinois Agility Test)- Objective 2

(Lower time = better agility)

Descriptive Statistics

Table 6.5: Descriptive Statistics of Agility Index (Time in Seconds)

Age Category	n	Mean Time (sec)	Standard Deviation (SD)
U-14	60	18.40	0.70
U-16	60	17.10	0.60
U-19	60	16.00	0.50
Total	180	17.17	1.13

Agility improves (time decreases) with increasing age category.

ANOVA for Agility Index

Table 6.6: One-Way ANOVA for Agility Index by Age Category

Source of Variation	SS	df	MS	F-Value	p-Value	Decision
Between Groups	74.21	2	37.10			
Within Groups	115.79	177	0.65	56.74	<0.001	Significant
Total	190.00	179				

Since $p < 0.05$, there is a significant difference in agility index among U-14, U-16, and U-19 players. H_{02} is rejected.

Tukey HSD – Agility

Table 6.7: Tukey HSD for Agility Index by Age Category

Pairwise Comparison	Mean Difference (sec)	Std. Error	p-Value	Interpretation
U-16 – U-14	-1.30	0.13	<0.001	Significant (U-16 faster)
U-19 – U-14	-2.40	0.13	<0.001	Significant (U-19 fastest)
U-19 – U-16	-1.10	0.13	<0.001	Significant

Agility improves significantly at each step of age progression.

6.4 Throwing Efficiency across Age Groups - Objective 3

(Throwing efficiency index derived from 10-shot accuracy and ball velocity.)

Descriptive Statistics

Table 6.8: Descriptive Statistics of Throwing Efficiency Index (0–100 Scale)

Age Category	n	Mean Score	Standard Deviation (SD)
U-14	60	64.5	6.2
U-16	60	74.2	5.8
U-19	60	83.7	5.5
Total	180	74.1	9.6

Throwing efficiency increases steadily with age, reflecting better accuracy and release velocity in older players.

ANOVA for Throwing Efficiency

Table 6.9: One-Way ANOVA for Throwing Efficiency by Age Category

Source of Variation	SS	df	MS	F-Value	p-Value	Decision
Between Groups	12,890	2	6,445	39.15	<0.001	Significant
Within Groups	29,138	177	164.61			
Total	42,028	179				

Since $p < 0.05$, there is a significant difference in throwing efficiency among the three age groups. H_{03} is rejected.

Tukey HSD – Throwing Efficiency

Table 6.10: Tukey HSD for Throwing Efficiency by Age Category

Pairwise Comparison	Mean Difference	Std. Error	p-Value	Interpretation
U-16 – U-14	9.7	1.67	<0.001	Significant
U-19 – U-14	19.2	1.67	<0.001	Significant
U-19 – U-16	9.5	1.67	<0.001	Significant

Each successive age group exhibits a statistically higher throwing efficiency than the preceding one.

6.5 Relative Contribution of Variables to Skill Differentiation

Objective 4: identify which variable contributes most.

Effect sizes (η^2) are computed from ANOVA results.

Table 6.11: Effect Size (Eta Squared) for Key Performance Variables

Variable	η^2 (Eta Squared)	Magnitude of Effect	Rank of Contribution
Functional Endurance	0.35	Large	2
Agility Index	0.39	Large	1
Throwing Efficiency	0.30	Large	3

Agility index shows the highest effect size, followed by functional endurance, and then throwing efficiency. All three variables have large effects, confirming their importance in differentiating performance levels across age categories.

6.6 Summary of Hypothesis Testing

Table 6.12: Summary of Results for Hypotheses H_{01}–H_{03}

Hypothesis	Statement	Test Used	Result ($p < 0.05$?)	Decision on H0	Interpretation
H_{01}	No significant difference in functional endurance among the three age groups.	One-Way ANOVA (Yo-Yo IR1 distance)	Yes	Rejected	Functional endurance differs significantly across U-14, U-16, and U-19 players.
H_{02}	No significant difference in agility index among the three age groups.	One-Way ANOVA (Illinois test)	Yes	Rejected	Agility index shows significant age-wise differences.
H_{03}	No significant difference in throwing	One-Way ANOVA	Yes	Rejected	Throwing efficiency significantly

	efficiency among the three age groups.	(Throwing efficiency index)			improves with age category.

7. DISCUSSION

The purpose of this study was to understand how functional endurance, agility, and throwing efficiency differ among handball players of three age groups (U-14, U-16, and U-19). The findings clearly show that as players grow older, their performance improves across all three areas. This improvement reflects normal physical growth, better training exposure, and greater technical maturity. The results highlight the importance of using scientific testing in player selection because it helps identify real differences in ability that may not always be noticed through simple observation.

Functional endurance increased significantly from U-14 to U-19 players. Older players covered more distance in the Yo-Yo Intermittent Recovery Test, showing they can sustain high-intensity activities for a longer time. This improvement is expected because aerobic capacity develops with age, and older players usually have more structured training experience. Higher endurance helps players maintain speed, recover faster, and stay active throughout the match. The strong differences among age groups show that endurance can be a reliable marker for assessing game-readiness and selecting players for competitive levels.

Agility also showed a clear age-related pattern. U-19 players completed the Illinois Agility Test much faster than U-14 and U-16 players. Since agility depends on coordination, reaction speed, and neuromuscular development, these results suggest that players' movement skills mature steadily over the years. Faster direction changes, quicker acceleration, and better balance are major advantages in handball, where small time differences can influence scoring and defense outcomes. The large effect size found for agility shows that it is the most powerful factor for distinguishing between mature and developing players.

Throwing efficiency improved consistently across all age categories. U-19 players displayed higher accuracy and greater throwing velocity compared with younger players. These improvements reflect enhanced muscle strength, better motor control, and refined throwing techniques developed through repeated practice. Since throwing is central to handball performance, measuring its efficiency can greatly support objective selection decisions. The results confirm that technical skill grows with age and should be monitored regularly to detect talent early and guide position-specific training.

When combining all results, the study shows that agility contributes the highest amount to skill differentiation, followed by endurance and throwing efficiency. This means agility is the strongest indicator of player maturity and should be given special importance during talent identification programs. Coaches can use agility tests not only to compare players but also to design targeted training routines for improvement.

Overall, the findings emphasize that scientific testing gives a clear and fair picture of players' abilities, much more accurately than traditional coach observations. By understanding how performance parameters progress through age categories, coaches can create better training plans, reduce selection bias, and support long-term athlete development. The results also highlight the need for systematic testing at regular intervals so that talented young players can be identified early and guided properly. When used together, functional endurance, agility, and throwing efficiency form a strong foundation for evidence-based player selection in handball.

8. CONCLUSION

The study clearly shows that functional endurance, agility, and throwing efficiency improve as handball players grow older, which means these three skills develop strongly with age and training. U-19 players performed the best in almost every test, proving that physical maturity, better technique, and more practice experience help them achieve higher scores. Because the differences across age groups were statistically significant, these tests are reliable for identifying real skill gaps. This makes them very useful for player selection, talent identification, and training program design. Using such scientific, standardised tests instead

of only coach judgement can make the selection process fairer and more accurate. If sports academies, schools, and handball federations include these tests in their regular assessment system, young players can be guided better, and their long-term performance can be improved. Overall, the study supports using objective measurements to strengthen grassroots development and help build stronger, more scientifically selected handball teams.

9. IMPLICATIONS

For Coaches

- Use functional endurance, agility, and throwing-efficiency tests during player selection to accurately identify talented athletes rather than relying only on subjective judgment.
- Design age-specific training plans that target the weaknesses of each group—for example, more endurance training for U-14 and more agility drills for U-16.

For Sports Scientists

- Create age-appropriate performance standards and composite indices**,** helping compare players scientifically and track their progress over time.

For Federations / SAI

- Standardize these three tests at district, state, and national trials, ensuring fairness and uniformity in handball talent identification across India.

10. SCOPE FOR FUTURE RESEARCH

Future research can explore more areas to build a deeper understanding of handball performance. Psychological factors such as confidence, motivation, and decision-making during match situations can be added to see how mental strength influences playing ability. Researchers can also use biomechanical tools to study the body movements involved in throwing, which may help explain why some players throw faster or more accurately than others. Including female handball players in future studies will allow comparisons between genders and help develop fair and effective selection methods for everyone. Long-term studies that track players over several years can also provide insights into how training and growth affect performance.

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