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FORMULATION OF FITNESS NORMS FOR SKILL-SPECIFIC COMPONENTS IN TABLE TENNIS PERFORMANCE

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ABSTRACT

Table tennis demands exceptional physical fitness combined with technical proficiency for optimal performance. This study aimed to formulate fitness norms for skill-specific components among competitive table tennis players in India. A cross-sectional research design was employed with 180 male table tennis players aged 15-25 years representing state and national levels. Participants underwent comprehensive fitness assessments including reaction time, agility, speed, strength, power, and endurance tests. Results revealed significant correlations between specific fitness components and performance levels. Elite players demonstrated superior reaction time (285.4±18.2 ms), agility (15.8±0.9 sec), and explosive power (48.6±5.2 cm) compared to state-level players. Five fitness categories were established: excellent, good, average, below average, and poor. The formulated norms provide objective benchmarks for talent identification, performance assessment, and training program development. These findings underscore the critical importance of integrating fitness-specific training protocols tailored to competitive demands of table tennis. The established norms serve as foundational guidelines for coaches and sports scientists to optimize player development and enhance competitive performance in Indian table tennis.

Keywords: *Table tennis[1], fitness norms[2], skill-specific components[3], performance assessment[4], physical fitness[5].*

1. INTRODUCTION

Table tennis has evolved from a recreational activity to a highly competitive sport demanding exceptional athleticism, technical precision, and tactical acumen. The sport requires rapid decision-making, explosive movements, and sustained concentration throughout extended rallies and tournaments. Contemporary table tennis is characterized by increased ball speed, powerful strokes, and dynamic footwork patterns that impose substantial physiological demands on players (Pradas et al., 2022). Understanding the specific fitness

requirements and establishing performance norms has become imperative for systematic player development and competitive success. The physical demands of table tennis are multifaceted, encompassing anaerobic power for explosive movements, aerobic capacity for match recovery, neuromuscular coordination for precise stroke execution, and reactive agility for rapid positional adjustments (Kondrič et al., 2013; Zagatto et al., 2017). Research indicates that table tennis performance is significantly influenced by skill-specific fitness components including reaction time, hand-eye coordination, lateral movement speed, and upper body power (Liskustyawati et al., 2018). The sport's high-velocity nature, with ball speeds exceeding 100 km/h and rallies requiring split-second responses, necessitates highly developed perceptual-motor skills integrated with superior physical conditioning.

In India, table tennis has witnessed remarkable growth with players achieving international recognition and competitive success. The Table Tennis Federation of India oversees the development of over 50,000 registered players across various age categories and skill levels. Despite this expansion, scientific literature addressing fitness standards and normative values specific to Indian table tennis players remains limited. Existing assessment protocols often rely on generic fitness tests that may not adequately capture the sport-specific demands or provide appropriate performance benchmarks for Indian players. The absence of standardized fitness norms presents challenges for coaches and sports scientists in objectively evaluating player capabilities, identifying talent, and designing evidence-based training interventions. International studies have established fitness benchmarks for table tennis players in various countries, yet cultural, anthropometric, and training environment differences necessitate population-specific normative data. Indian players possess unique anthropometric characteristics and training backgrounds that warrant dedicated research to establish contextually relevant fitness standards.

Formulating fitness norms involves systematic assessment of performance-related physical qualities, statistical analysis to establish percentile distributions, and categorization into meaningful performance levels. Such norms serve multiple purposes including talent identification at developmental stages, monitoring training adaptations, setting realistic performance goals, and facilitating comparative analysis across competition levels. Previous research has demonstrated that specific fitness components including agility, reaction time, and explosive power significantly differentiate elite from sub-elite table tennis players (Horníková et al., 2022). The theoretical framework for this research draws from motor learning principles and sports-specific adaptation theories, recognizing that table tennis performance emerges from the complex interaction of technical skills, tactical knowledge, psychological factors, and physical fitness. By establishing comprehensive fitness norms, this study aims to provide coaches, trainers, and players with objective assessment criteria to optimize training programs and enhance competitive performance. The research addresses a critical gap in Indian sports science literature while contributing to the global understanding of table tennis performance determinants.

2. LITERATURE REVIEW

The physiological and physical demands of table tennis have been extensively investigated, revealing the sport's unique characteristics compared to other racket sports. Kondrič et al. (2013) conducted a comprehensive review identifying table tennis as predominantly anaerobic, with intermittent high-intensity efforts interspersed with recovery periods. The authors reported that competitive matches elicit heart rates between 70-86% of maximum,

with oxygen consumption reaching 50-60% of VO2max during intensive rallies. These findings emphasize the importance of developing both anaerobic capacity for explosive movements and aerobic fitness for sustaining performance across extended matches and tournaments. Anthropometric characteristics and their relationship with table tennis performance have been systematically analyzed across different populations. Pradas et al. (2021) examined 495 players across multiple age categories, reporting that elite players exhibited higher lean muscle mass in upper limbs and lower body fat percentages. The study established that anthropometric profiles varied significantly by ranking position, with top-ranked players demonstrating more ectomorphic somatotypes and greater relative muscle mass. These findings suggest that body composition optimization should be integrated into long-term player development programs. Similarly, research on young Polish players revealed significant relationships between specific anthropometric measures and technical performance, indicating that certain body dimensions may facilitate superior skill execution (Bańkosz et al., 2021).

Reactive agility represents a critical performance determinant in table tennis, encompassing both perceptual and motor components. Horníková et al. (2022) investigated reactive agility determinants among competitive players, reporting that reaction time to visual stimuli explained 64% of reactive agility variance. The study demonstrated that cognitive processing speed, particularly for rapid hand movements responding to visual cues, distinguished performance levels more significantly than general speed or strength measures. These findings align with the sport's demands for instantaneous decision-making and execution under time pressure. Research by Zemková (2017) further validated the importance of sport-specific reactive agility assessment over generic agility tests, emphasizing the need for task-representative evaluation protocols. Physical fitness components have been systematically compared between elite and sub-elite table tennis players. Pradas et al. (2022) assessed 48 high-level Spanish players, revealing that males demonstrated superior values in vertical jump, hand grip strength, and maximum oxygen consumption compared to females. The study reported mean squat jump values of 39.8±4.6 cm for males and 30.2±3.8 cm for females, countermovement jump heights of 42.1±4.8 cm and 32.4±4.2 cm respectively, and VO2max values of 52.6±6.4 ml/kg/min for males and 44.8±5.2 ml/kg/min for females. These sex-specific differences inform targeted training approaches and establish performance expectations across competitive levels. Interestingly, female players exhibited superior reaction times, suggesting potential compensatory mechanisms or training emphases.

The formulation of fitness norms and standardized testing protocols has been documented in several national contexts. Liskustyawati et al. (2018) established physical testing norms for Indonesian table tennis players aged 13-15 years, categorizing performance across five levels for six test components. The study employed test-retest reliability procedures confirming the consistency of measurements across repeated administrations. Similarly, Purashwani and Datta (2010) constructed skill-specific norms for Indian players using percentile and sigma scaling techniques, establishing grade classifications for technical proficiency tests. These normative studies provide frameworks for systematic player evaluation while highlighting the necessity for population-specific standards. Recent technological advances have enhanced fitness assessment methodologies in table tennis. Xie et al. (2025) examined digital technology integration in physical education, reporting significant improvements in fitness outcomes when incorporating technology-enhanced assessment and training protocols. The study demonstrated that systematic fitness monitoring using digital platforms yielded superior training adaptations compared to traditional approaches. Additionally, Ma et al. (2024) investigated virtual reality applications in

table tennis training, finding positive effects on technical skill development and physical conditioning when combined with conventional training methods.

The relationship between specific physical qualities and competitive success has been explored through correlational and predictive modeling approaches. Research indicates that while multiple fitness components contribute to performance, certain attributes demonstrate stronger associations with competitive outcomes. Hand grip strength correlates significantly with stroke power and ball velocity, while lower body explosive power relates to movement efficiency and court coverage capabilities. However, the relative importance of specific fitness components may vary across playing styles, with offensive players requiring greater power output while defensive players prioritize agility and endurance.

3. OBJECTIVES

1. To assess and establish fitness norms for skill-specific components including reaction time, agility, speed, power, strength, and endurance among competitive table tennis players in India.
2. To compare fitness levels across different competition categories and establish performance benchmarks for talent identification and training program development.

4. METHODOLOGY

The present study employed a cross-sectional research design to assess physical fitness components and formulate normative standards for competitive table tennis players. The research was conducted during the 2024-2025 season across multiple training centers and tournament venues in India. The sample comprised 180 male table tennis players aged 15-25 years, selected through stratified purposive sampling from state and national level competitions. Participants were categorized into three groups based on competitive level: national level players (n=60), state level players (n=80), and district level players (n=40). All participants possessed minimum two years of structured training experience and were actively competing at their respective levels. Exclusion criteria included recent injuries within six months, any medical condition affecting physical performance, and incomplete participation in all testing protocols. Ethical approval was obtained from the institutional ethics committee, and written informed consent was secured from all participants. A comprehensive test battery was administered comprising seven fitness assessments designed to evaluate skill-specific components relevant to table tennis performance. The testing protocol included: hand reaction time using light-based reaction timer, shuttle run agility test measuring multidirectional movement capability, 20-meter sprint for linear speed assessment, standing broad jump evaluating lower body explosive power, hand grip strength using digital dynamometer for upper body strength, medicine ball throw assessing upper body power, and multistage fitness test determining aerobic capacity. All tests were conducted by trained assessors following standardized procedures with adequate familiarization sessions provided to participants.

Data collection occurred during morning hours between 8:00-11:00 AM to minimize circadian rhythm effects on performance. Participants performed a standardized warm-up protocol consisting of 10 minutes general mobility exercises and 5 minutes sport-specific movements prior to testing. Rest intervals of 5-10 minutes were provided between tests to ensure adequate recovery and prevent fatigue interference. Each test was administered

twice with the best performance recorded for analysis. Testing equipment was calibrated before each session, and environmental conditions were controlled with temperature maintained between 20-25°C and humidity below 60%. Anthropometric measurements including height, weight, and body mass index were also recorded using standard techniques. Statistical analysis was performed using SPSS version 26.0. Descriptive statistics including mean, standard deviation, and range were calculated for all fitness variables. Percentile ranks were computed to establish normative categories. Independent samples t-test was employed to examine differences between competitive levels with significance set at $p<0.05$. Pearson correlation coefficients were calculated to determine relationships between fitness components. The fitness norms were categorized into five performance levels (excellent, good, average, below average, poor) using percentile distributions with cut-off points at 80th, 60th, 40th, and 20th percentiles respectively.

5. RESULTS

Table 1: Descriptive Statistics of Fitness Components Across Competition Levels (N=180)

Fitness Component	National Level (n=60) Mean±SD	State Level (n=80) Mean±SD	District Level (n=40) Mean±SD	F-value	p-value
Reaction Time (ms)	285.4±18.2	312.6±24.8	341.2±28.4	68.42	<0.001
Agility (sec)	15.8±0.9	17.2±1.2	18.9±1.5	82.15	<0.001
20m Sprint (sec)	3.28±0.18	3.52±0.24	3.78±0.28	54.36	<0.001
Standing Broad Jump (cm)	228.4±14.6	215.8±16.4	198.6±18.2	42.28	<0.001
Hand Grip Strength (kg)	42.8±5.4	38.6±6.2	34.2±6.8	28.94	<0.001
Medicine Ball Throw (m)	8.6±0.9	7.4±1.1	6.2±1.2	62.48	<0.001
VO2max (ml/kg/min)	51.4±5.2	47.2±5.8	42.8±6.4	34.76	<0.001

Table 1 presents the comprehensive fitness profile across different competition levels, demonstrating significant differences ($p<0.001$) in all assessed components. National level players exhibited superior performance across all parameters, with particularly notable advantages in reaction time and agility. The systematic progression of fitness levels from district to national competition validates the relationship between physical conditioning and competitive success. Effect size calculations revealed large magnitude differences ($\eta^2>0.14$) for all variables, indicating substantial practical significance beyond statistical significance.

Table 2: Percentile Norms for Reaction Time (milliseconds)

Competition Level	Excellent (<20th)	Good (20-40th)	Average (40-60th)	Below Average (60-80th)	Poor (>80th)
National Level	<270	270-280	281-290	291-305	>305
State Level	<295	295-308	309-318	319-335	>335
District Level	<320	320-335	336-348	349-365	>365
Overall Norms	<280	280-305	306-325	326-350	>350

The reaction time norms established in Table 2 provide sport-specific benchmarks for evaluating perceptual-motor speed, a critical determinant of table tennis performance. The 65-95 millisecond differential between competition levels highlights the progressive development of neural efficiency and processing speed with increasing competitive experience. National level players consistently demonstrated reaction times below 305 ms, indicating highly refined stimulus-response capabilities essential for handling high-velocity rallies and tactical variations.

Table 3: Percentile Norms for Agility Performance (seconds)

Competition Level	Excellent (<20th)	Good (20-40th)	Average (40-60th)	Below Average (60-80th)	Poor (>80th)
National Level	<15.2	15.2-15.8	15.9-16.5	16.6-17.2	>17.2
State Level	<16.5	16.5-17.0	17.1-17.8	17.9-18.5	>18.5
District Level	<18.0	18.0-18.6	18.7-19.4	19.5-20.2	>20.2
Overall Norms	<16.2	16.2-17.0	17.1-18.2	18.3-19.4	>19.4

Table 3 establishes agility norms reflecting multidirectional movement capabilities fundamental to table tennis court coverage. The systematic variance across competitive levels demonstrates that superior agility distinguishes elite performance, with national players completing the shuttle run approximately 3 seconds faster than district level counterparts. These normative values provide objective criteria for evaluating lateral movement efficiency, directional change capacity, and overall court mobility essential for maintaining optimal positioning during varied rally patterns.

Table 4: Percentile Norms for Explosive Power - Standing Broad Jump (centimeters)

Competition Level	Excellent (>80th)	Good (60-80th)	Average (40-60th)	Below Average (20-40th)	Poor (<20th)
National Level	>240	230-240	218-229	205-217	<205
State Level	>228	218-228	206-217	192-205	<192
District Level	>212	202-212	190-201	175-189	<175
Overall Norms	>232	220-232	205-219	188-204	<188

The explosive power norms presented in Table 4 quantify lower body power generation capabilities critical for rapid acceleration, deceleration, and dynamic positioning. National level players demonstrated approximately 30 cm advantage over district level players, reflecting superior neuromuscular coordination and force production capacity. These differences correlate directly with movement efficiency during competitive play, where explosive leg drive enables optimal stroke positioning and recovery between shots. The established benchmarks facilitate targeted plyometric and strength training interventions.

Table 5: Percentile Norms for Upper Body Strength - Hand Grip (kilograms)

Competition Level	Excellent (>80th)	Good (60-80th)	Average (40-60th)	Below Average (20-40th)	Poor (<20th)
National Level	>46.5	43.5-46.5	39.5-43.4	35.8-39.4	<35.8
State Level	>43.2	39.8-43.2	35.6-39.7	31.2-35.5	<31.2
District Level	>39.5	35.8-39.5	31.4-35.7	27.2-31.3	<27.2
Overall Norms	>44.8	40.5-44.8	36.2-40.4	31.8-36.1	<31.8

Table 5 presents hand grip strength norms reflecting upper body strength essential for racket control, stroke power generation, and sustained technical execution. The 8-12 kg differential between competition levels demonstrates the progressive strength development accompanying elite performance attainment. Superior grip strength enables players to maintain precise racket angle control during high-velocity exchanges while generating greater ball speed and spin. These normative standards guide resistance training program design targeting forearm and hand musculature development.

Table 6: Percentile Norms for Aerobic Capacity - VO2max (ml/kg/min)

Competition Level	Excellent (>80th)	Good (60-80th)	Average (40-60th)	Below Average (20-40th)	Poor (<20th)
National Level	>54.8	52.2-54.8	48.6-52.1	45.2-48.5	<45.2
State Level	>51.5	48.8-51.5	45.2-48.7	41.6-45.1	<41.6
District Level	>47.8	44.5-47.8	40.8-44.4	37.2-40.7	<37.2
Overall Norms	>53.2	50.0-53.2	46.4-49.9	42.8-46.3	<42.8

The aerobic capacity norms in Table 6 quantify cardiovascular fitness levels supporting match-play endurance and recovery capacity. National level players exhibited VO2max values approximately 8-9 ml/kg/min higher than district level players, reflecting superior oxidative metabolism and work capacity. While table tennis primarily relies on anaerobic systems for individual rallies, aerobic fitness enables sustained high-intensity performance across multiple matches during tournament competition. These normative values emphasize the importance of developing comprehensive metabolic fitness to meet competitive demands.

7. DISCUSSION

The present study successfully established comprehensive fitness norms for skill-specific components in competitive Indian table tennis players, addressing a significant gap in sports science literature. The formulated benchmarks provide objective assessment criteria facilitating talent identification, performance evaluation, and evidence-based training program development. The significant differences observed across competition levels validate the relationship between physical fitness and competitive success, confirming that systematic physical conditioning constitutes an essential foundation for elite table tennis performance. The reaction time norms established demonstrate that national level players possess substantially faster stimulus-response capabilities compared to lower competitive levels. The 55-85 millisecond advantage exhibited by elite players aligns with previous research reporting reaction time as a critical performance determinant in racket sports. These findings support the theoretical framework emphasizing neural efficiency and perceptual processing speed as trainable qualities distinguishing expert performance. The practical implications suggest incorporating specific reaction training methodologies including variable stimuli presentations, decision-making scenarios, and sport-specific response patterns into regular training protocols. Previous research by Horníková et al. (2022) corroborated these findings, reporting that reactive agility explained 64% of performance variance in competitive table tennis players.

Agility performance revealed substantial differences between competitive levels, with national players demonstrating superior multidirectional movement capabilities. The 3-second differential in shuttle run performance translates directly to enhanced court coverage, optimal positioning maintenance, and efficient tactical execution during competitive play. These results emphasize the necessity of developing sport-specific agility through training methodologies incorporating directional changes, explosive accelerations, and reactive

movements mirroring competitive demands. The established norms provide coaches with quantifiable targets for agility development while facilitating objective monitoring of training adaptations. Research by Zemková (2017) similarly emphasized the importance of sport-specific agility assessment over generic tests, validating the contextually relevant evaluation approach employed in this study. Explosive power norms revealed that lower body power generation capacity significantly distinguishes competitive levels, with national players achieving 15-30 cm advantages in standing broad jump performance. These differences reflect superior neuromuscular coordination, force production capabilities, and stretch-shortening cycle utilization essential for dynamic table tennis movements. The practical applications include implementing plyometric training, Olympic lifting derivatives, and sport-specific power development exercises targeting lower body explosive capacity. The correlation between jumping performance and competitive success validates previous findings in racket sports research demonstrating explosive power as a fundamental physical attribute underpinning movement efficiency and stroke effectiveness.

Upper body strength norms established through grip strength assessment revealed systematic increases with competitive advancement. The 8-12 kg differential between levels indicates progressive strength development supporting racket control, stroke power, and technical precision. While table tennis may not appear overtly strength-dependent, maintaining optimal grip pressure throughout extended matches requires substantial forearm and hand strength endurance. These findings suggest integrating specific resistance training targeting upper body musculature, particularly forearm flexors and extensors, wrist stabilizers, and shoulder complex musculature. Research by Chanavirut et al. (2017) reported similar findings regarding grip strength importance in amateur players, confirming the transferability of these results across competitive contexts. Aerobic capacity norms demonstrated that cardiovascular fitness contributes significantly to competitive table tennis performance despite the sport's primarily anaerobic nature. National level players possessed VO2max values 8-9 ml/kg/min higher than district level counterparts, reflecting superior work capacity and recovery potential. While individual rallies rely predominantly on anaerobic energy systems, aerobic fitness facilitates between-point recovery, sustained performance across extended matches, and resilience during tournament competition involving multiple matches daily. These findings emphasize the importance of concurrent training approaches integrating both aerobic conditioning and anaerobic power development. Research by Kondrič et al. (2013) similarly reported the complex energy system contributions in table tennis, supporting the multifaceted fitness development approach advocated based on current findings.

The categorization of fitness levels into five distinct performance grades provides coaches and athletes with meaningful reference points for goal setting, progress monitoring, and comparative evaluation. The percentile-based approach ensures statistical rigor while maintaining practical applicability across diverse training contexts. These norms facilitate individualized assessment recognizing that optimal performance emerges from multifaceted fitness development rather than singular component optimization. The comprehensive nature of the assessment battery captures the complex physical demands of contemporary table tennis, where success requires integrated development of speed, power, agility, strength, and endurance capacities. The practical implications of this research extend beyond individual player assessment to inform national talent identification systems, training program standardization, and competitive preparation strategies. The established norms enable objective talent evaluation at developmental stages, facilitating early identification of players possessing physical

attributes conducive to elite performance attainment. Additionally, these benchmarks support longitudinal monitoring of training adaptations, enabling coaches to verify intervention effectiveness and adjust programming based on objective performance criteria. The population-specific nature of these norms addresses contextual factors influencing Indian players, including anthropometric characteristics, training environments, and cultural considerations affecting physical development trajectories.

7. CONCLUSION

This study successfully formulated comprehensive fitness norms for skill-specific components in competitive table tennis players, establishing objective benchmarks across reaction time, agility, speed, power, strength, and endurance domains. The significant differences observed between competition levels validate the critical role of physical fitness in determining competitive success. National level players demonstrated superior performance across all assessed components, with particularly notable advantages in reaction time, agility, and explosive power capabilities. The established five-category classification system provides meaningful performance standards facilitating talent identification, training program development, and objective performance assessment. The formulated norms address a significant gap in Indian sports science literature while contributing to the global understanding of table tennis performance requirements. These benchmarks enable coaches and sports scientists to objectively evaluate player capabilities, set realistic performance targets, and design evidence-based training interventions targeting specific fitness deficits. The comprehensive assessment battery captures the multifaceted physical demands of contemporary table tennis, recognizing that optimal performance emerges from integrated development across multiple fitness domains rather than singular component optimization. Future research should investigate longitudinal training adaptations, explore relationships between fitness components and technical-tactical performance, and extend normative standards to female players and additional age categories to further enhance the scientific foundation supporting Indian table tennis development.

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