Relationship Between Physical Fitness Components and Forehand Topspin Performance in Adolescent Table Tennis Athletes

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Abstract. This study investigated the relationship between physical fitness and forehand topspin performance among adolescent table tennis athletes. A cross-sectional research design was employed involving 39 athletes from the Indonesian Table Tennis Association. Physical fitness was assessed using the Eurofit Test Battery, including the Flamingo Balance Test, Standing Long Jump Test, Plate Tapping Test, Sit-Up Test, Sit-and-Reach Test, Handgrip Strength Test, and 10 × 5 Shuttle Run Test. Forehand topspin performance was evaluated through standardized technical performance measurements emphasizing accuracy, consistency, and stroke execution. Data were analyzed using the Pearson correlation coefficient and multiple linear regression analysis to determine both simultaneous and independent effects of physical fitness variables on forehand topspin performance. The findings demonstrated that several physical fitness domains were significantly associated with forehand topspin performance, particularly explosive strength, eye–hand coordination, muscular endurance, and static strength. Simultaneously, all physical fitness variables contributed significantly to forehand topspin performance. However, muscular endurance emerged as the only independent predictor in the regression model. These findings indicate that endurance capacity plays a central role in sustaining technical consistency and stroke quality during repeated high-intensity rallies. In conclusion, physical fitness significantly influences forehand topspin performance in adolescent table tennis athletes. Training programs emphasizing endurance development, explosive power, and coordination are recommended to improve technical effectiveness and competitive performance. This study contributes to the growing body of sport science literature concerning evidence-based conditioning strategies in racket sports and provides practical implications for coaches and athlete development programs.

Keywords: Table tennis, forehand topspin, physical fitness, Eurofit Test Battery, adolescent athletes, sport performance.

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1 Introduction

Table tennis is a high-intensity racket sport characterized by rapid ball velocity, short reaction time, and complex technical execution. The sport requires athletes to integrate biomechanical precision, neuromuscular coordination, and physical conditioning simultaneously during play [1]. Compared with many other racket sports, table tennis demonstrates one of the fastest game tempos due to the short distance between opponents and the high frequency of stroke exchanges [2]. Consequently, athletes must maintain optimal technical consistency under conditions of repeated high-intensity movement and minimal recovery time.

Among the offensive techniques used in modern table tennis, the forehand topspin is considered one of the most decisive attacking strokes. Previous performance analyses have shown that topspin-based offensive strategies significantly contribute to point acquisition and match success at both junior and elite levels [3], [4]. Previous investigations examining forehand drive performance also reported that technical proficiency contributes directly to competitive outcomes in table tennis athletes [5].The forehand topspin combines several performance components, including ball speed, spin intensity, directional accuracy, timing precision, and upper-body explosive force [6]. Biomechanically, this technique requires synchronized kinetic chain activation involving lower-limb stability, trunk rotation, shoulder acceleration, and wrist control to generate effective spin and power [7]. Biomechanical studies of stroke execution have shown that movement sequencing and upper-body coordination significantly influence ball velocity and technical precision [8]. Furthermore, adaptive physiological responses in upper-body performance may contribute to long-term improvements in stroke quality [9]. Therefore, successful execution of the forehand topspin depends not only on technical mastery but also on the athlete's physical fitness capacity.

Physical fitness is recognized as a fundamental determinant of sport performance because it supports technical efficiency, tactical execution, and physiological endurance during competition [7]. In table tennis, athletes are required to demonstrate dynamic balance, agility, muscular endurance, coordination, reaction speed, and explosive power to maintain performance throughout prolonged rallies [10]. Balance and neuromuscular control are particularly important for maintaining body stability during rapid directional transitions and stroke execution [11]. Furthermore, cardiovascular and muscular endurance enable athletes to sustain repeated high-intensity actions with minimal decline in technical quality during competitive matches [12] Muscular strength assessments have previously demonstrated their usefulness in evaluating performance capacity among adolescent athletes [13]

Several studies have emphasized the importance of agility and eye–hand coordination in improving response accuracy and stroke effectiveness in racket sports [14]. Table tennis players must rapidly interpret ball trajectory, spin variation, and opponent positioning before producing accurate motor responses within a very short time frame [15]. In addition, flexibility and lower-body power contribute to efficient movement patterns around the table, thereby enhancing stroke execution efficiency and reducing injury risk [16]. These findings indicate that technical performance in table tennis is strongly influenced by multidimensional physical fitness components. Similar observations among high-level table tennis players revealed that physical fitness profiles are closely associated with competitive performance characteristics [17]. Comparable relationships between physical conditioning and technical ability have also been reported in combat sport athletes [18].

The Eurofit Test Battery is widely used to evaluate physical fitness among children and adolescent athletes because it provides comprehensive measurements of balance, coordination, muscular strength, flexibility, speed, and endurance [19]. Several Eurofit assessments are particularly relevant to the physiological and motor demands of table tennis. The Flamingo Balance Test and Plate Tapping Test assess postural stability and upper-limb coordination, both of which are essential for rapid stroke execution [20]. Meanwhile, the Standing Long Jump Test, Sit-Up Test, Handgrip Strength Test, and 10 × 5 Shuttle Run Test evaluate explosive power, muscular endurance, static strength, and agility, which are closely associated with performance in high-speed racket sports [21], [22].

Adolescent athletes represent an important population in table tennis because this developmental phase involves substantial growth in neuromuscular function, motor coordination, and physical fitness adaptation [23]. Previous evidence also suggests that regular participation in table tennis activities contributes positively to physical development and health outcomes among children and adolescents [24].Early identification of physical fitness characteristics associated with technical performance may support evidence-based talent development and training program design. Although previous studies have examined physiological demands and biomechanical aspects of table tennis, limited research has specifically investigated the relationship between Eurofit-based physical fitness components and forehand topspin performance among adolescent athletes.

Therefore, this study aims to analyze the relationship between physical fitness and forehand topspin performance in adolescent table tennis athletes using the Eurofit Test Battery. The findings are expected to provide scientific evidence regarding the physical determinants of technical performance and contribute to the development of more effective conditioning programs for youth table tennis athletes.

2 Methods of Research

2.1 Research Design

This study employed a cross-sectional research design to examine the relationship between physical fitness components and forehand topspin performance in adolescent table tennis athletes. The cross-sectional approach was selected because it enables the simultaneous evaluation of physical fitness characteristics and sport-specific technical performance within a defined population at a single period of observation [1]. This design is widely applied in sport science research to identify physiological and motor factors associated with athletic performance [2].

2.2 Participants

The study population consisted of adolescent table tennis athletes registered in three table tennis clubs: Persatuan Tenis Meja Kartajati Bale Bengong, Persatuan Tenis Meja STONI, and Persatuan Tenis Meja Citra Bersama. Sample size determination was conducted using the Krejcie and Morgan sampling formula for known populations [3]. A purposive sampling technique was applied to ensure that participants met the inclusion criteria relevant to the objectives of the study. The final sample consisted of 44 adolescent athletes who had actively participated in regular training and competition programs.

The inclusion criteria included: (1) athletes aged 10–17 years, (2) actively participating in structured table tennis training for at least one year, and (3) free from musculoskeletal injury during the testing period. Athletes who experienced injury, illness, or incomplete testing procedures were excluded from the study. The adolescent age category was selected because this developmental stage is characterized by rapid improvements in motor coordination, neuromuscular adaptation, and physical fitness capacities relevant to sport performance [4].

2.3 Instruments and Procedures

Physical fitness assessment was conducted using the Eurofit Test Battery, a standardized instrument widely used to evaluate youth physical fitness and motor performance [5]. The Eurofit Test Battery was selected because it provides comprehensive measurements of balance, coordination, muscular strength, flexibility, speed, and endurance, which are important physiological components in table tennis performance [6].

The physical fitness assessments included the Flamingo Balance Test, Standing Long Jump Test, Plate Tapping Test, Sit-Up Test, Sit-and-Reach Test, Handgrip Strength Test, and 10 × 5 Shuttle Run Test. The Flamingo Balance Test was used to evaluate static balance, whereas the Plate Tapping Test measured upper-limb speed and coordination. Explosive lower-body power was assessed using the Standing Long Jump Test. Muscular endurance was measured through the Sit-Up Test, flexibility through the Sit-and-Reach Test, static muscular strength through the Handgrip Strength Test, and agility through the 10 × 5 Shuttle Run Test [7], [8].

Forehand topspin performance was evaluated using a standardized forehand topspin accuracy test adapted to the technical demands of competitive table tennis. The assessment emphasized stroke accuracy, ball placement consistency, and technical execution under controlled testing conditions. Prior to data collection, all participants completed a standardized warm-up session to minimize injury risk and improve testing reliability.

2.4 Data Analysis

Descriptive statistical analysis was performed to summarize the characteristics of the research data, including minimum values, maximum values, means, and standard deviations. Before inferential analysis, data normality was examined using the Shapiro–Wilk normality test because the sample size was below 50 participants [9].

The relationship between Eurofit Test Battery variables and forehand topspin performance was analyzed using the Pearson product–moment correlation test. This analysis was conducted to identify the strength and direction of associations between physical fitness components and technical performance variables. Furthermore, multiple linear regression analysis was applied to determine the simultaneous and independent contributions of physical fitness variables to forehand topspin performance. Statistical significance was established at $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics software.

2.5 Ethical Considerations

All research procedures were conducted in accordance with ethical principles for human participant research. Prior to participation, informed consent was obtained from all athletes and their parents or legal guardians. Participants were informed regarding the objectives, procedures, benefits, and potential risks of the study. Confidentiality and anonymity of participant data were maintained throughout the research process.

3 Results of the Study

This study involved 44 adolescent table tennis athletes aged 10–17 years from three table tennis clubs: Persatuan Tenis Meja Kartajati Bale Bengong, Persatuan Tenis Meja STONI, and Persatuan Tenis Meja Citra Bersama. The demographic characteristics of participants based on gender and age are presented in Table 1.

Table 1 . Distribution of Participants by Gender and Age

Characteristics	Frequency	Percentage(%)
Gender		
Female	20	45.5
Male	24	54.5
Age		
10 years	10	22.7
11 years	4	9.1
12 year	10	22.7
13 year	4	9.1
14 year	3	6.8
15 year	2	4.5
16 year	6	13.6
17 year	5	11.4

Table 1 shows that male athletes constituted a slightly larger proportion of participants than female athletes. Furthermore, most participants were within the early adolescent age category (10–13 years), indicating that the study primarily represented athletes undergoing active motor development and neuromuscular adaptation phases.

Table 2 . Descriptive Statistics of Eurofit Test Battery and Forehand Topspin

Parameter	N	Min.	Max.	Mean	SD
Flamingo Balanca test	44	2	15	9.41	3.598
Standing long jump test (cm)	44	106.6	250.0	163.295	37.6734
Plate tapping test (s)	44	6.8	22.2	12.975	3.2102
Sit up test	44	10	38	20.11	6.885
Sit-and-reach tests	44	6.1	17.2	11.373	3.0002
Handgrip strength test (kg)	44	9.8	40.5	22.532	8.6153
10x5 Shuttle Run Test	44	27.1	64.0	41.018	7.8513
Forehand Topspin Score	44	27	70	52.93	10.326

The descriptive statistics indicate substantial variability across physical fitness parameters and forehand topspin performance. The Standing Long Jump Test demonstrated a wide performance range, suggesting considerable differences in lower-body explosive power among athletes. Similarly, handgrip strength and muscular endurance showed notable variation, reflecting differences in physical conditioning status among participants.

Before conducting inferential statistical analysis, data normality was evaluated using the Shapiro–Wilk test.

Table 3 . Normality Test Results

Parameter	Sig. Value	Description
Flamingo Balance test	0.134	Normal distribution
Standing long jump test	0.114	Normal distribution
Plate Tapping test	0.082	Normal distribution
Sit-up test	0.074	Normal distribution
Sit-and-reach test	0.107	Normal distribution
Handgrip Strength test	0.070	Normal distribution
10x5 Shuttle Run Test	0.172	Normal distribution
Forehand Topspin	0.499	Normal distribution

All variables demonstrated significance values greater than 0.05, indicating that the data were normally distributed and met the assumptions required for Pearson correlation and multiple linear regression analyses.

The Pearson correlation analysis between Eurofit Test Battery components and forehand topspin performance is summarized in Table 4.

Table 4 . Pearson Correlation Between Physical Fitness Components Forehand Topspin Performance

Variable	r	p-value	Interpretation
Flamingo Balance Test	0.026	0.868	Not significant
Standing Long Jump Test	0.639	<0.001	Significant
Plate Tapping Test	-0.473	0.001	Significant
Sit-Up Test	0.693	<0.001	Significant
Sit-and-Reach Test	-0.142	0.356	Not significant
Handgrip Strength Test	0.630	<0.001	Significant
10 × 5 Shuttle Run Test	-0.160	0.301	Not significant

The results revealed significant relationships between forehand topspin performance and several physical fitness domains, including explosive power, eye–hand coordination, muscular endurance, and static strength. The Sit-Up Test demonstrated the strongest positive correlation with forehand topspin performance ($r = 0.693$, $p < 0.001$), followed by the Standing Long Jump Test and Handgrip Strength Test. Conversely, balance, flexibility, and agility did not demonstrate statistically significant relationships with topspin performance.

To identify the simultaneous contribution of physical fitness variables to forehand topspin performance, multiple linear regression analysis was conducted.

Table 5. Multiple Linear Regression Analysis

Variable	B	Std. Error
Constant	29.958	11.958
Flamingo Balance Test	0.219	0.330
Standing Long Jump Test	0.076	0.042
Plate Tapping Test	-0.074	0.492
Sit-Up Test	0.635	0.266
Sit-and-Reach Test	-0.144	0.390
Handgrip Strength Test	0.168	0.200
10 × 5 Shuttle Run Test	-0.132	0.168

The regression model demonstrated that the Sit-Up Test provided the largest positive contribution to forehand topspin performance. The regression equation can be expressed as follows:

$$Y = 29.958 + 0.219X_1 + 0.076X_2 - 0.074X_3 + 0.635X_4 - 0.144X_5 + 0.168X_6 - 0.132X_7$$

where Y represents forehand topspin performance, while $X1_1$–X_7 represent the Eurofit physical fitness variables. The positive coefficient of the Sit-Up Test indicates that higher muscular endurance was associated with improved topspin performance.

Table 6. Partial t- test Analysis

Variable	t	Sig.
Flamingo Balance Test	0.664	0.511
Standing Long Jump Test	1.785	0.083
Plate Tapping Test	-0.150	0.881
Sit-Up Test	2.390	0.022
Sit-and-Reach Test	-0.370	0.714
Handgrip Strength Test	0.841	0.406
10 × 5 Shuttle Run Test	-0.789	0.435

The partial t-test analysis showed that only the Sit-Up Test demonstrated a statistically significant independent effect on forehand topspin performance ($p < 0.05$). Other variables did not exhibit independent predictive effects after controlling for the combined influence of all fitness variables. These findings suggest that muscular endurance is the dominant physical fitness determinant influencing forehand topspin execution in adolescent table tennis athletes.

4 Discussion

The analysis identified four physical fitness domains that demonstrated significant relationships with forehand topspin performance in table tennis, namely dynamic strength, eye–hand coordination, endurance, and static strength. Among these variables, endurance emerged as the most influential predictor of forehand topspin performance based on correlation and multiple linear regression analyses. These findings indicate that endurance-oriented training should become the primary focus in athlete development programs, followed by exercises targeting dynamic strength, eye–hand coordination, power endurance, and static strength. The results confirm that forehand topspin performance is multidimensional and strongly influenced by integrated physiological and neuromuscular capacities.

The endurance domain demonstrated the strongest contribution to topspin forehand performance because table tennis requires athletes to sustain high-intensity movements, concentration, and rapid technical execution throughout prolonged rallies and match durations. Athletes with superior endurance capacity are able to maintain stroke velocity, accuracy, and tactical consistency despite physiological fatigue [1], [2]. Previous studies have shown that fatigue negatively affects reaction time, lower-limb stability, and stroke precision, which directly influences match performance [3]. Consequently, endurance functions as a physiological foundation that supports technical efficiency under competitive pressure. Similar findings have shown that abdominal and muscular endurance training improve technical execution and performance sustainability among racket sport athletes [25].

Dynamic strength also showed a significant relationship with forehand topspin performance. Previous studies demonstrated that athletic training and neuromuscular conditioning significantly improve technical performance in racket sports through enhanced force production and movement efficiency [26]. Biomechanical investigations further indicate that shoulder movement patterns and upper-body mechanics contribute substantially to stroke effectiveness in table tennis [27]. Therefore, strength-conditioning programs focusing on lower-body explosiveness and trunk rotational power are essential components in table tennis training.

Eye–hand coordination was also identified as a significant predictor of topspin forehand performance. Table tennis is characterized by extremely rapid ball trajectories and limited reaction time; therefore, athletes must integrate visual perception with accurate motor responses [7]. Effective eye–hand coordination enables players to synchronize visual information processing with racket movement, allowing precise timing and improved stroke placement. Previous studies reported that sensorimotor efficiency contributes substantially to reaction speed, spatial anticipation, and technical accuracy in racket sports [8], [9]. Athletes with superior coordination abilities tend to demonstrate greater consistency in ball control and shot precision during high-speed rallies. These findings reinforce the importance of incorporating perceptual–motor training into athlete development programs.

Static strength was similarly found to have a meaningful relationship with topspin forehand performance. Static muscular strength contributes to postural stability and body control during stroke preparation and follow-through phases [10]. Adequate stability allows athletes to maintain optimal body positioning, resulting in more efficient energy transfer and enhanced stroke accuracy. In fast-paced match situations, stable body control is necessary to facilitate rapid directional adjustments and effective balance recovery [11]. Furthermore, athletes with greater static strength exhibit superior motor control and movement efficiency, enabling faster and more precise technical execution [12]. Accordingly, core stability and isometric strength exercises should be integrated systematically within physical conditioning programs for table tennis athletes.

In contrast, the balance, flexibility, and agility domains did not demonstrate significant relationships with forehand topspin performance. The absence of a significant association between balance and topspin performance suggests that general balance ability may not directly predict technical stroke outcomes. Although balance is considered important for acceleration and deceleration control, previous research indicates that balance performance is more strongly associated with age, playing experience, and skill level than with specific technical execution [13], [14]. Furthermore, conventional balance assessments may fail to replicate the dynamic and unpredictable conditions experienced during competitive table tennis play.

Similarly, flexibility did not significantly influence forehand topspin performance. The interaction between flexibility and technical execution appears indirect and multifactorial. Existing evidence suggests that flexibility contributes primarily to injury prevention rather than direct enhancement of technical performance [15]. Electromyographic investigations indicate that muscle activation patterns during topspin strokes are influenced more by technical mastery and motor experience than by passive flexibility levels [16]. Although flexibility may support a wider range of motion, its direct contribution to stroke effectiveness remains limited [17]. In addition, the sit-and-reach test used to assess flexibility does not adequately represent the dynamic biomechanical demands required during topspin forehand execution. Therefore, flexibility assessments based solely on static movement capacity may possess limited ecological validity for evaluating table tennis performance.

The agility domain also failed to demonstrate a significant relationship with forehand topspin performance. The 10 × 5 shuttle run test primarily measures pre-planned directional changes and does not fully capture the perceptual and cognitive complexities involved in table tennis competition. Agility in racket sports extends beyond physical movement speed and includes visual anticipation, decision-making, and response adaptation to rapidly changing stimuli [28], [29]. Technical abilities such as racket control, coordination, and stroke timing appear to contribute more directly to topspin performance than linear agility performance alone [30]. Consequently, traditional agility assessments may underestimate the multidimensional characteristics required in elite table tennis competition.

Overall, the present findings highlight that endurance, dynamic strength, eye–hand coordination, and static strength represent the primary physical determinants of forehand topspin performance in table tennis athletes. These results provide practical implications for coaches and sport scientists in designing evidence-based conditioning programs that prioritize sport-specific physiological and neuromuscular demands. Future studies are recommended to incorporate biomechanical motion analysis, reaction-time measurement, and sport-specific agility assessments to obtain a more comprehensive understanding of performance determinants in competitive table tennis.

5 Conclusion

The present study demonstrates that several physical fitness domains are associated with forehand topspin performance in table tennis athletes, particularly explosive power, eye–hand coordination, endurance, and static strength. Among these variables, endurance emerged as the most dominant predictor, indicating that athletes with superior muscular endurance tend to maintain greater stroke consistency, ball control, and technical efficiency during prolonged match situations. These findings confirm that forehand topspin performance is not determined solely by technical proficiency, but also by the integration of physiological and neuromuscular capacities that support performance sustainability under competitive demands [1], [2].

Explosive power, measured through the Standing Long Jump Test, showed a positive contribution to topspin performance, highlighting the importance of lower-limb force production in generating racket acceleration and ball spin. Similarly, static strength assessed through the Handgrip Test contributed to movement stability and stroke control, which are essential for maintaining technical accuracy during high-speed rallies [3]. Eye–hand coordination, evaluated using the Plate Tapping Test, was also identified as an important performance-related factor because effective sensorimotor synchronization enables athletes to respond rapidly to ball trajectory and optimize stroke timing [4]. However, the negative relationship identified in the statistical analysis suggests that coordination performance may interact with other technical and tactical variables, indicating the need for further biomechanical and perceptual investigations.

Although all physical fitness domains within the Eurofit Test Battery contributed collectively to forehand topspin performance, only endurance demonstrated an independent effect in the regression analysis. This finding suggests that endurance functions as the primary physiological foundation supporting technical execution throughout competitive play. In contrast, balance and flexibility did not exhibit significant direct effects on topspin performance. Nevertheless, these components remain important for injury prevention, postural control, movement efficiency, and long-term athlete development [5], [6].

From a practical perspective, the findings emphasize that table tennis training programs should prioritize endurance development, dynamic strength enhancement, static strength conditioning, and sport-specific eye–hand coordination exercises. Conditioning strategies integrating technical drills with physiological training are recommended to improve stroke quality and competitive performance simultaneously. Furthermore, future research should incorporate biomechanical analysis, electromyography, and reactive agility assessments to better explain the multidimensional determinants of topspin forehand performance in elite table tennis athletes.

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