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Research Article

An Observational Study to Analyze the Impact of Static and Dynamic Balance, Agility and Change of Direction Speed In Young Athletes

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ABSTRACT

Background: Athletic performance in youth sports is shaped by a wide spectrum of neuromuscular and biomechanical factors, among which static balance, dynamic balance, agility, and change of direction speed (CODS) hold a foundational place. These performance components serve as the building blocks of nearly every skill executed in sport - from simple posture control to complex movement sequences requiring strength, coordination, precision, and rapid adaptation. Together, they influence how efficiently a young athlete can maintain bodily control, adjust to external demands. This study was designed to examine the interrelationship between static balance, dynamic balance, agility, and change of direction speed (CODS) in young athletes aged 12–18 years.

Objective: The objective of the study is to i) evaluate static balance performance in young athletes, ii) assess dynamic balance abilities during functional movement tasks, iii) measure agility performance in young athletes iv) assess change of direction speed (CODS) during pre-planned directional tasks.

Methods: 60 Recreational and competitive athletes are participated who are involved in the sports with agility and balance (for example, badminton, football, basketball, and athletics) for at least 3 days per week during the last 6 months. Participants proceed to the testing site, fill in a demographic and screening form.

Outcome measure: Stork Stand Test, “Y” shape, Hexagon Agility Test, T-test is used for measuring pre and post intervention evaluation.

Results: This data suggests that most athletes in the study possessed reasonably good directional speed and movement efficiency, likely due to regular participation in sports requiring rapid directional changes.

Conclusion: A strong relationship was observed between agility and change of direction speed, indicating that athletes who are more agile also tend to perform better in COD tasks. Age-related analysis showed that older athletes demonstrated superior dynamic balance, agility, and COD performance, likely due to improved neuromuscular coordination, strength, and movement efficiency with growth and maturation. Static balance showed minimal improvement with age, suggesting that dynamic movement control continues to develop throughout adolescence.

Keywords: Static Balance, Dynamic Balance, Agility, and Change of Direction Speed (CODS), Athletes.

INTRODUCTION

Athletic performance in youth sports is shaped by a wide spectrum of neuromuscular and biomechanical factors, among which static and dynamic balance, agility, and change-of-direction speed (CODS) hold a foundational place. These performance components serve as the building blocks of nearly every skill executed in sport,from simple posture control to complex movement sequences requiring strength, coordination, precision, and rapid adaptation. Together, they influence how efficiently a young athlete can maintain bodily control, adjust to external demands, transition smoothly between movements, and execute sport-specific tasks under varying degrees of physical load and cognitive challenge(1,2).

In youth populations, where motor skills are still developing and neuromuscular systems are highly adaptable, these abilities become even more critical. Children and adolescents experience rapid physical changes as they progress through growth spurts, hormonal shifts, and increases in training exposure (3).These developmental phases bring both opportunities and vulnerabilities. On the one hand, the neuromuscular system is highly receptive to training stimuli, allowing balance, agility, and speed-related qualities to improve significantly with structured practice. On the other hand, immature coordination, evolving musculoskeletal structures, and fluctuating strength levels make young athletes more susceptible to movement inefficiencies and sport-related injuries(4).

As young athletes move through progressively competitive environments, the demands on their bodies increase dramatically. They are expected to respond quickly to unpredictable game situations, sustain high-intensity workloads, and demonstrate precision in movement despite fatigue or external pressure(5). This requires a refined interaction between sensory systems, motor output, muscular strength, joint stability, and cognitive processing. Therefore, developing strong foundations in balance, agility, and CODS is essential not only for immediate performance enhancement but also for long-term athlete development (LTAD), a framework emphasizing safe, progressive, and sustainable growth in sport(6).

Moreover, these components influence far more than athletic success. A high level of balance and coordinated movement helps young athletes build confidence, improve body awareness, reduce the risk of overuse injuries, and develop efficient movement strategies that can carry over into adulthood. Modern sports science recognizes that training these qualities early can significantly enhance an athlete's resilience and preparedness for high-level sport later in life. In this sense, balance, agility, and CODS are not merely performance variables; they are cornerstones of healthy athletic growth, motor learning, and injury prevention (7).

Dynamic balance significantly influences an athlete's movement fluidity and performance capability. High levels of dynamic balance allow for smoother transitions between actions, more effective energy transfer through the kinetic chain, and quicker responses to opponents or environmental cues. For example, a basketball player performing a sudden sidestep to create space, a footballer cutting sharply to evade a defender, a volleyball player landing safely after a spike, or a badminton player lunging explosively toward the shuttleall rely heavily on well-developed dynamic balance(8).

Additionally, dynamic balance contributes to the precision and accuracy of sport-specific skills. Movements such as striking a ball, executing a jump shot, or initiating a sprint depend on stable lower-limb mechanics and correct alignment during transitional phases. When dynamic balance is inadequate, athletes compensate with inefficient strategies that compromise accuracy, power output, and movement speed (9).

The most critical role of dynamic balance lies in injury prevention. Research consistently shows that poor dynamic balance is strongly associated with lower-limb injuries, particularly:

- Knee valgus collapse,
- Anterior cruciate ligament (ACL) injuries,
- Patellofemoral pain syndrome (PFPS),
- Ankle sprains,
- Muscle strains during high-speed tasks.

These injuries often occur during high-demand movements such as landing from a jump or performing a rapid directional change. Without adequate balance control, athletes struggle to distribute forces evenly across joints, increasing the load on vulnerable structures. Dynamic balance helps ensure the body remains aligned and controlled, even in the face of instability, thereby reducing biomechanical stresses that contribute to injury (10).

Agility is one of the most critical physical qualities in modern sports performance, especially in dynamic, fast-paced environments where athletes must respond quickly to unpredictable situations. Traditionally, agility was narrowly defined as the ability to change direction rapidly. However, contemporary sports science recognizes agility as a multidimensional skill that integrates physical, cognitive, perceptual, and reactive components. This means that agility is not only about how fast an athlete can move, but also about how quickly they can think, perceive, decide, and execute movements under pressure (11).

In young athletes, agility reflects the efficiency of neuromuscular coordination combined with their ability to read game situations and respond appropriately. Sports such as football, basketball, rugby, hockey, badminton, and tennis require athletes to constantly track moving objects, anticipate opponents' movements, and adjust their trajectories within fractions of a second. These demands make agility essential for competitive success across almost all youth sports.

From a physical perspective, agility depends on a combination of strength, speed, dynamic balance, postural control, joint mobility, and motor coordination. Athletes must decelerate rapidly, control their center of mass, reposition their limbs, and then explosively accelerate in a new direction. This sequence requires significant eccentric strength, neuromuscular precision, and efficient energy redistribution. For young athletes whose neuromuscular systems are still developing, agility training can accelerate motor learning, improve tendon stiffness, and refine biomechanical efficiency (12).

Change of direction speed (CODS) is another essential physical quality that significantly influences athletic performance, particularly in sports that require quick, pre-planned movement transitions. CODS refers to the athlete's ability to rapidly decelerate, change direction, and accelerate again along a predetermined path. Unlike agility, which incorporates reactive and perceptual decision-making, CODS tests the athlete's pure physical capacity to execute planned directional changes efficiently.

CODS is considered a direct measure of neuromuscular power, eccentric strength, coordination, and mechanical efficiency during directional transitions. Because athletes must slow down, lower their center of gravity, stabilize the joints, and reorient their body before accelerating again, CODS reflects the quality of their movement mechanics and lower-limb strength. Efficient CODS requires a seamless integration of:

- Eccentric strength for deceleration
- Isometric strength for stabilization
- Concentric power for re-acceleration
- Core stability for trunk control
- Lower-limb alignment to absorb and redirect forces
- Foot-ground contact efficiency to minimize time lost during transitions(13,14,15)

In youth athletes, CODS performance is strongly influenced by their stage of growth and neuromuscular maturity. During adolescence, rapid increases in limb length and body mass can temporarily disrupt coordination, making CODS an especially sensitive indicator of developmental changes. Athletes who demonstrate poor CODS during growth spurts often show compensatory patterns such as knee valgus collapse, excessive trunk lean, or delayed force production—patterns that increase injury risk and reduce performance.

The development of athletic performance in youth is a complex process shaped by the interplay of neuromuscular control, biomechanical efficiency, motor coordination, and physical maturation. Among the many components that contribute to successful performance, static balance, dynamic balance, agility, and change of direction speed (CODS) stand out as fundamental determinants of movement quality and sport-specific capability (16,17,18). Despite their importance, these attributes are often inadequately assessed or insufficiently trained in early stages of athletic development, especially within school- and community-level sports programs (19,20).

The rationale for investigating the relationship between balance, agility, and CODS in youth athletes stems from several critical concerns in contemporary sports science. First, young athletes are in a period of rapid growth and neuromuscular adaptation. During these developmental phases, motor patterns are highly malleable, making this the most influential time to shape long-term movement efficiency. Understanding how static and dynamic balance relate to agility and CODS allows coaches and therapists to design targeted interventions that can prevent improper movement patterns from becoming ingrained (21,22).

Second, balancing both static and dynamic serves as the foundation for nearly every athletic action. Deficits in balance control frequently manifest as poor landing mechanics, unstable foot placement, trunk deviation, or delayed neuromuscular responses, which, in turn, impair agility and directional speed. Without adequate balance, athletes struggle to generate force efficiently or distribute loads safely through the lower extremities, increasing the risk of acute injuries such as ankle sprains and ACL ruptures, as well as chronic issues like patellofemoral pain. Investigating how balance affects agility and CODS provides essential insight into the mechanics of injury prevention and safe performance progression (23,24,25).

Third, agility and CODS are indispensable qualities in most competitive sports. These abilities allow athletes to outmaneuver opponents, adapt to unpredictable situations, execute rapid transitions, and maintain high performance intensity. Yet, empirical evidence suggests that agility is not merely a product of strength or speed; rather, it relies on intricate interactions between balance, proprioception, decision-making, and neuromuscular coordination (26,27). CODS, on the other hand, isolates the physical aspects of directional changes, highlighting deficits in strength, technique, or motor control that may not be apparent in open-reactive agility tasks(28).By simultaneously analyzing balance, agility, and CODS, this study seeks to develop a holistic understanding of youth athletic capabilities(29,30,31). Furthermore, despite the significant role these components play in performance and injury prevention, there remains a gap in research on their interrelationships in young athletes, particularly in the Indian sporting context (32,33). Most existing literature has evaluated these variables independently or among adult or elite populations. A comprehensive observational study involving youth athletes provides unique insight into how these physical traits co-develop during adolescence, how they influence one another, and how they collectively shape overall athletic ability(34,35,36,37). Lastly, the findings of this study have practical implications for coaches, physical educators, clinicians, and sports academies(38,39).By identifying which balanceaspects most strongly predict agility and CODS, training programs can be tailored to prioritize exercises that yield the greatest performance improvements. This approach enhances training efficiency, reduces injury risk, and supports talent identification by highlighting athletes with superior neuromuscular qualities (40).

MATERIAL AND METHOD

Study Design: Observational study

Sample Design: Convenience Sampling

Sample Size & Study population: 60 Recreational and competitive athletes are participated who are involved in the sports with agility and balance (for example, badminton, football, basketball, and athletics) for at least 3 days per week during the last 6 months were selected and assessed for the pre-test parameter.

Study Setting: Participants were evaluated at sports centre, Pacific Medical College and hospital. UDAIPUR.

Study Duration: one year

Inclusion Criteria

1. **Age Range:** Young athletes aged 12 to 18 years.
2. **Gender:** Both male and female participants.
3. **Activity Level:** Recreational and competitive athletes who are involved in the sports with agility and balance (for example, badminton, football, basketball, and athletics) for at least 3 days per week during the last 6 months.
4. **Health Status**: Clinically healthy people who currently do not suffer from musculoskeletal, neurological or cardiopulmonary impairments.
5. **Consent**: Voluntary participation (e.g., ability to give written informed consent (or assent with written parent/guardian consent in the case of a minor)).

Exclusion Criteria

1. **History of Recent Injury**: Any lower limb and/or spine injury that occurred in the last 6 months which may impede performance in agility or balance tests.
2. **Neurological Disorders**: Neurological disorders that have been identified (e.g., cerebral palsy, multiple sclerosis, stroke), which interfere with balance or movement.
3. **Orthopaedic Surgeries**: History of orthopedic surgery in the last year.
4. **Visual or Vestibular Impairments**: Well-known visual, vestibular, or proprioceptive deficits.
5. **Medication Use:** Use of drugs that may possibly mess up with balance, coordination or reaction times.
6. **Lack of Compliance:** Participants who are unwilling and unable to follow instructions and go through the testing procedures.

Procedure

Permission for conduct Study is taken from the institutional ethical committee of PMCH (Protocol no. PMU/IEC/MPT/2025/65), Pacific medical university bhilo ka bedla Udaipur(RAJ). Athletes initially assessed for the inclusion or exclusion criteria. Prior to the procedure, all participants were informed about the purpose, procedures, potential benefits, and possible risks of the study. Written informed consent was obtained from each participant prior to enrollment.

Participants will proceed to the testing site, fill in a demographic and screening form.

There will be a prescribed 10-minute warm up.

Jogging – light jog around the gym or track for 5 min to elevate heart and prepare muscles

Arm/Leg swings

Dynamic Stretches: example includes walking lunges, high knees, butt kicks, and hip circles-each for around 30 seconds

Main Exercises

Balance Exercises
1. Single-leg stands (stable and unstable surfaces)
2. BOSU Ball Squats
3. Y-Balance Reach Drill

Agility Drills
1. Ladder Drills
2. Cone Drills (Shuttle Runs)
3. Plyometric Hops and Zig-Zag Jumps

Change of Direction (COD) Training
1. 5-10-5 Drill (Pro Agility Drill)
   Set three cones in a straight line, 5 yards apart.
   Start at the middle cone, sprint 5 yards to the right cone, touch the line, sprint 10 yards to the far left cone, then return to the middle.
   Focus on quick direction changes and low center of gravity.
2. Box Drill
   Arrange four cones in a square (5x5 meters).
   Sprint forward, shuffle laterally, backpedal, and shuffle again to complete the box.
   Repeat in both clockwise and counterclockwise directions.
3. T-Drill Practice
   COOL DOWN (5 minutes)
   Static Stretching
   Hamstrings: Sit with legs straight, reach for toes.
   Quadriceps: Pull one foot behind to stretch the front thigh.
   Calves: Lean against a wall with one leg extended back.
   Hold each stretch for 20–30 seconds.
   Breathing Exercises

The following assessments will come in such order: Stork Stand Test, "Y" shape, Hexagon Agility Test, T-test(Three trials occur and a time (seconds) spent the best is recorded)
Data will be keyed in a master sheet to be analyzed statistically.

Data Collection
- **Testing Sessions**: The data collection will take place during testing sessions where the Participants will undergo the various performance assessments. Each testing session will consist of three trials to gather sufficient data for analysis.
- **Number of Trials**: The participants will perform three trials for each protocol or test. The purpose of conducting multiple trials is to account for individual variations, reduce the impact of outliers or measurement errors, and ensure more reliable data.
- **Trial Selection**: After completing the three trials, the best performance result from each participant will be selected for further analysis. The best result can be determined based on the fastest sprint time, highest jump height, and agility time .Selecting the best trial helps ensure that the recorded data represents the participants' optimal performance.
- **Data Management**: The recorded data will be appropriately organized and stored for analysis. It is crucial to maintain data integrity and ensure that the collected information is secure and easily accessible for further processing and statistical analysis.

Data Analysis and Results

Table 1: Age Distribution of Participants

Age Range (Years)	Frequency (N)	Percentage (%)
12–13 Years	10	16.7%
14–15 Years	18	30.0%
16–17 Years	22	36.7%
18 Years	10	16.7%
Total	**60**	**100**

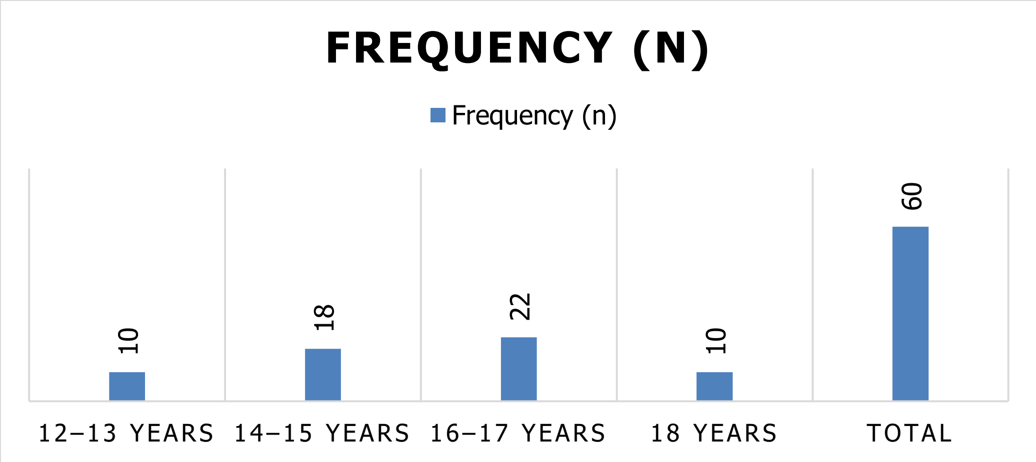
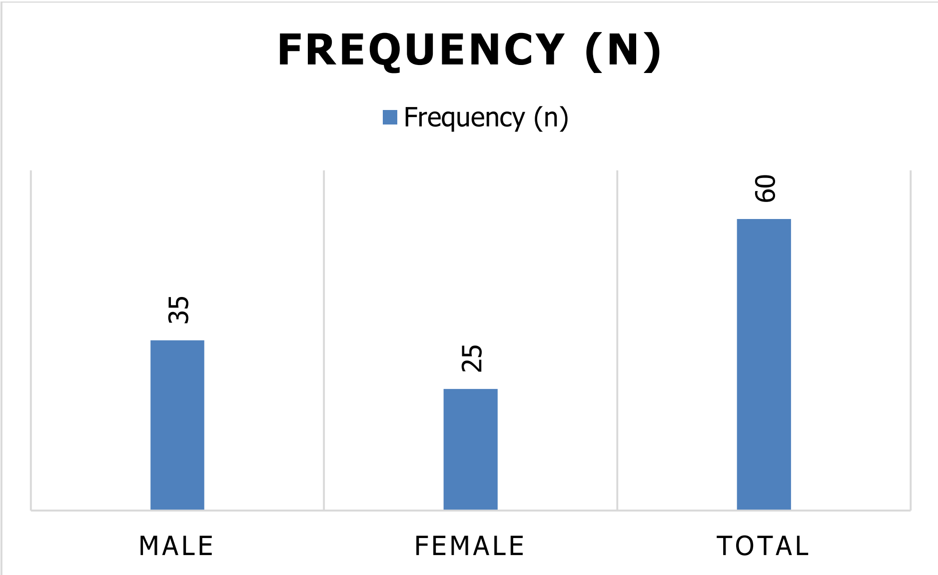


Table 2: Gender Distribution of Participants

Gender	Frequency (N)	Percentage (%)
Male	35	58.3%
Female	25	41.7%
Total	**60**	**100%**



This table and pie chart present the gender composition of the study participants.
Out of 60 athletes, 58.3% were males and 41.7% were females. The graph visually shows a slightly higher number of male athletes while maintaining strong female representation

Table 3: BMI Classification of Participants

Bmi Category	Bmi Range (Kg/M²)	Frequency (N)	Percentage (%)
Underweight	<18.5	8	13.3%
Normal Weight	18.5–24.9	40	66.7%
Overweight	25–29.9	10	16.7%
Obese	≥30	2	3.3%
Total		**60**	**100%**

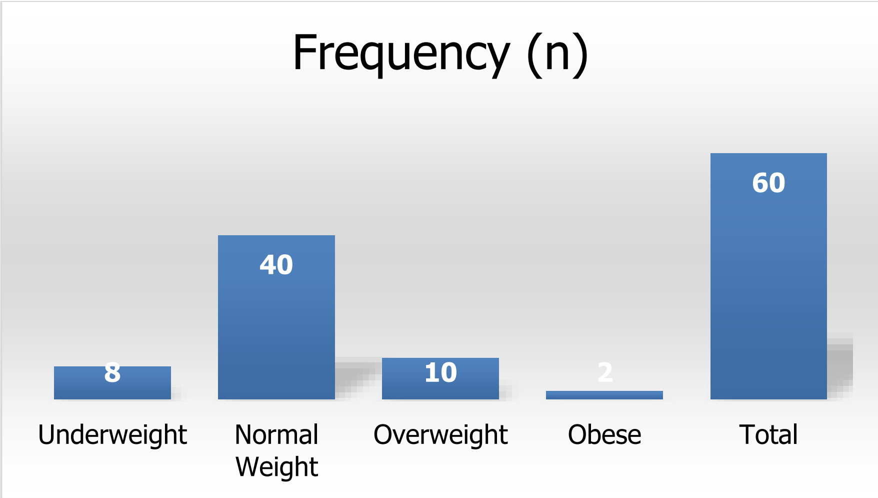
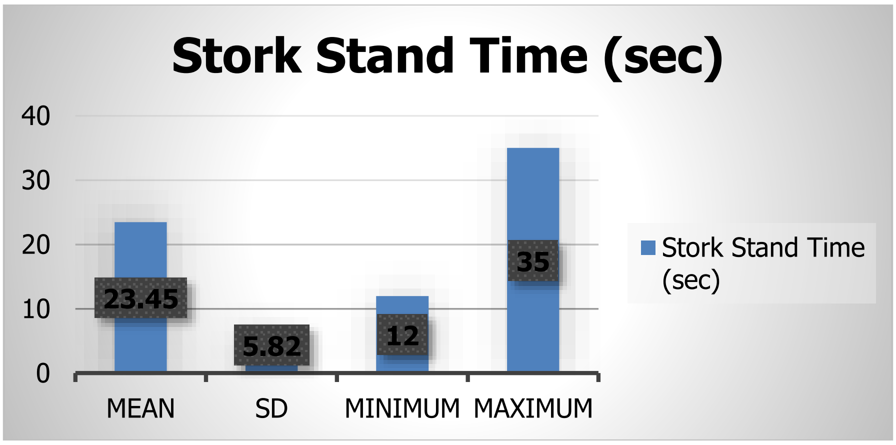


Table 3 and the Bar Graph Classify Participants According To Their Body Mass Index (BMI).

Table 4: Stork Stand Test (Static Balance)

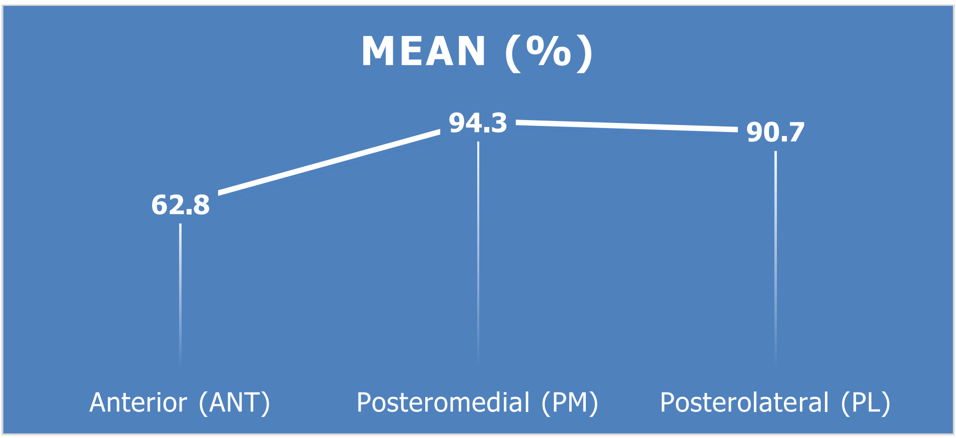
Variable	Mean	SD	Minimum	Maximum
Stork Stand Time (Sec)	23.45	5.82	12	35



Descriptive Statistics (Best of 3 Trials, Seconds)

Table 5: Y-Balance Test (Dynamic Balance)

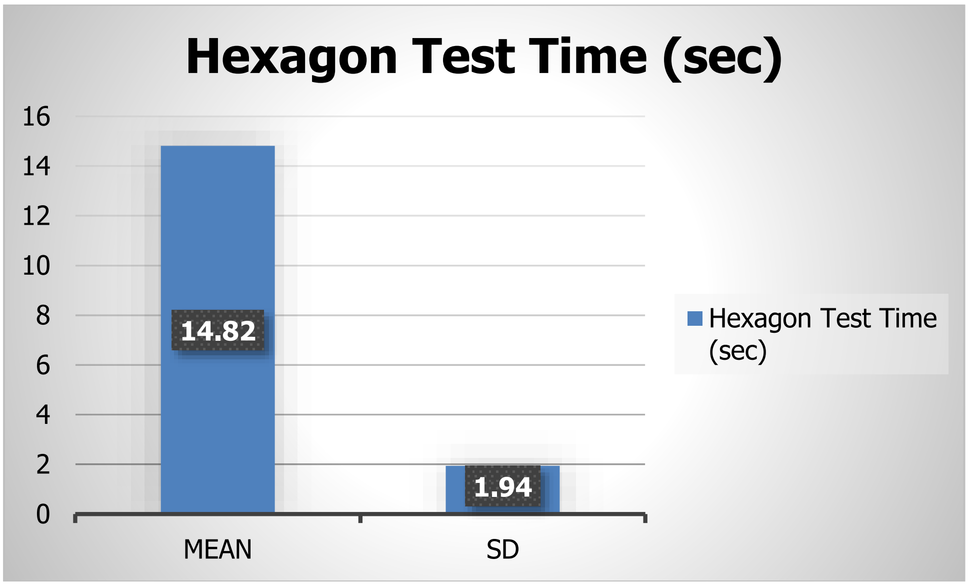
Direction	Mean (%)	SD (%)	Minimum (%)	Maximum (%)
Anterior (ANT)	62.8	4.9	52	74
Posteromedial (PM)	94.3	7.1	78	110
Posterolateral (PL)	90.7	6.5	75	108



Reach Distance (Normalized To Leg Length %) Based On 3 Directions

Table 6: Hexagon Agility Test

Variable	Mean	SD	Range (Min–Max)
Hexagon Test Time (Sec)	14.82	1.94	11.2 – 18.9



Agility Performance (Seconds)

This table and graph present agility performance based on completion time in seconds.

Table 7: T-Test (Change of Direction Speed)
COD Performance (Seconds)

Variable	Mean	SD	Range (Min–Max)
T-Test Time (Sec)	11.52	1.28	9.4 – 14.8

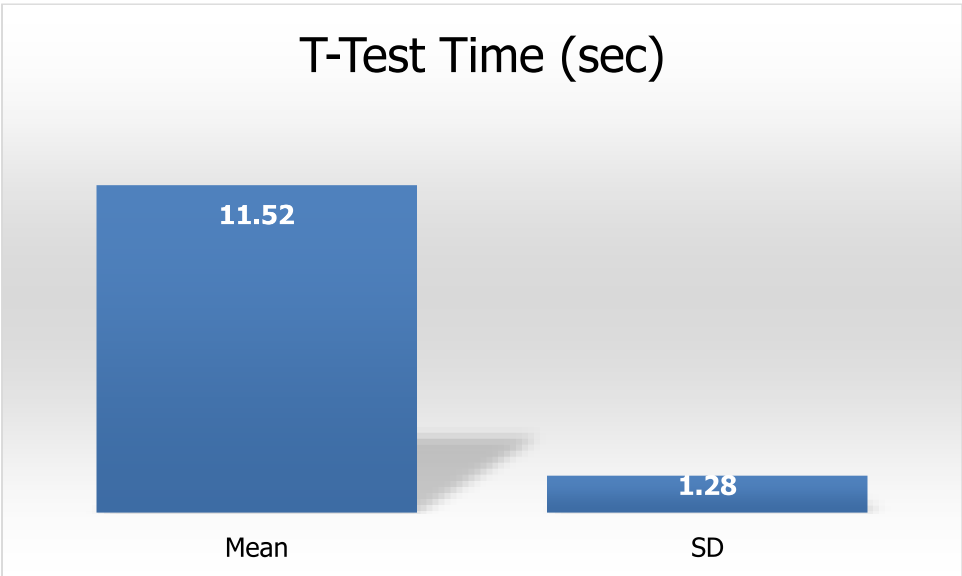


Table 7 and Its Graph Illustrate COD Speed Using The T-Test.

Table 8: Correlation Analysis

Correlation Pair	R-Value	P-Value	Interpretation
Bmi Vs Static Balance	-0.42	0.002*	Higher Bmi = Poorer Static Balance
Bmi Vs Dynamic Balance (Ant)	-0.31	0.015*	Higher Bmi Limits Forward Reach Stability

Bmi Vs Agility (Hexagon Test)	0.28	0.03*	Higher Bmi = Slower Agility
Bmi Vs Cod (T-Test)	0.34	0.01*	Higher Bmi Reduces Acceleration & Change-Of-Direction Speed
Age Vs Static Balance	0.22	0.08	Mild Improvement With Age (Ns)
Age Vs Dynamic Balance (Pm)	0.33	0.01*	Older Athletes Show Better Dynamic Stability
Age Vs Agility	-0.36	0.008*	Older Athletes Perform Faster
Age Vs Cod	-0.31	0.02*	Older Athletes Are Quicker At Cod
Static Balance Vs Hexagon Agility	-0.48	<0.001*	Better Static Balance = Faster Agility
Static Balance Vs Cod	-0.40	0.003*	Good Stability Improves Cod Performance
Dynamic Balance (Ant) Vs Hexagon	-0.44	0.001*	Forward Reach Stability Improves Agility
Dynamic Balance (Pm) Vs Hexagon	-0.49	<0.001*	Pm Reach Is A Strong Predictor Of Agility
Dynamic Balance (Pl) Vs Hexagon	-0.46	<0.001*	Pl Reach Linked With Lateral Agility
Dynamic Balance (Ant) Vs Cod	-0.38	0.005*	Better Dynamic Control Improves Cod
Dynamic Balance (Pm) Vs Cod	-0.51	<0.001*	Pm Reach Is The Best Predictor Of Cod
Dynamic Balance (Pl) Vs Cod	-0.47	<0.001*	Strong Lateral Dynamic Control = Faster Cod
Agility (Hexagon) Vs Cod	0.63	<0.001*	Elite Agility Strongly Predicts Cod Performance

*Significant at $p < 0.05$

Table 8 presents a correlation analysis examining the relationships among age, BMI, balance (static and dynamic), agility, and change-of-direction speed (COD) in young athletes. The correlation coefficient (r-value) indicates the strength and direction of the relationship, while the p-value shows whether the relationship is statistically significant. A negative r-value means that as one variable increases, the other decreases, whereas a positive r-value means both variables increase together. Relationships with $p < 0.05$ are considered statistically significant.

The analysis shows a moderate negative correlation between BMI and static balance ($r = -0.42$, $p = 0.002$), indicating that athletes with a higher BMI tended to have poorer static balance performance. Similarly, BMI showed a negative association with dynamic balance in the anterior direction ($r = -0.31$, $p = 0.015$), suggesting that increased body mass limits forward reach stability. In addition, BMI showed positive correlations with agility time ($r = 0.28$, $p = 0.03$) and COD time ($r = 0.34$, $p = 0.01$). Since higher times represent poorer performance, this finding indicates that athletes with higher BMI generally performed more slowly during agility and change-of-direction tasks.

Age-related correlations revealed that age had a mild positive relationship with static balance ($r = 0.22$, $p = 0.08$); however, this relationship was not statistically significant, suggesting that static balance improves slightly with age but not consistently. In contrast, age showed a significant positive correlation with dynamic balance in the posteromedial direction ($r = 0.33$, $p = 0.01$), indicating that older athletes demonstrated better dynamic stability. Age also showed moderate negative correlations with agility ($r = -0.36$, $p = 0.008$) and COD performance ($r = -0.31$, $p = 0.02$), indicating that as age increased, athletes completed agility and COD tasks faster. This reflects improvements in neuromuscular coordination and movement efficiency with maturation.

Strong relationships were observed between balance and performance variables. Static balance showed moderate negative correlations with agility ($r = -0.48$, $p < 0.001$) and COD ($r = -0.40$, $p = 0.003$), indicating that athletes who maintained better postural stability performed faster during agility and directional changes. Dynamic balance showed even stronger associations. Anterior reach demonstrated significant negative correlations with agility ($r = -0.44$, $p = 0.001$) and COD ($r = -0.38$, $p = 0.005$). Posteromedial reach showed the strongest relationships with both agility ($r = -0.49$, $p < 0.001$) and COD ($r = -0.51$, $p < 0.001$), making it the best predictor of high-level movement performance. Posterolateral reach also showed strong negative correlations with agility ($r = -0.46$, $p < 0.001$) and COD ($r = -0.47$, $p < 0.001$), emphasizing the importance of lateral stability in sports performance.

Finally, agility and COD were strongly positively correlated ($r = 0.63$, $p < 0.001$), indicating that athletes who performed well in agility tasks also demonstrated faster change-of-direction speed. This strong relationship highlights that agility and COD are closely linked motor qualities, relying on similar neuromuscular, balance, and coordination demands.

Table 9: Performance Classification of Athletes (n = 60)

Test	Excellent n (%)	Above Average n (%)	Average n (%)	Below Average n (%)
Stork Stand (Static Balance)	12 (20%)	18 (30%)	20 (33.3%)	10 (16.7%)
Y-Balance (Dynamic Balance)	15 (25%)	22 (36.7%)	18 (30%)	5 (8.3%)
Hexagon Agility Test	10 (16.7%)	20 (33.3%)	22 (36.7%)	8 (13.3%)
T-Test (COD Speed)	14 (23.3%)	21 (35%)	19 (31.7%)	6 (10%)

Table 9 presents the performance classification of 60 young athletes across four key physical performance tests: static balance (Stork Stand Test), dynamic balance (Y-Balance Test), agility (Hexagon Agility Test), and change-of-direction speed (T-Test). Athletes were categorized into Excellent, Above Average, Average, and Below Average based on their test scores, allowing a clear understanding of overall performance levels within the study population.For the Stork Stand Test, which assesses static balance, 20% of the athletes (n = 12) demonstrated excellent balance ability, indicating strong postural control during single-leg stance. A larger proportion, 30% (n = 18), fell into the above-average category, while 33.3% (n = 20) showed average performance. However, 16.7% (n = 10) were classified as below average, suggesting that a notable subgroup of athletes may have deficits in static postural stability that could affect movement initiation and injury risk.In the Y-Balance Test, which measures dynamic balance, the distribution was more favorable. 25% of athletes (n = 15) achieved excellent performance, and 36.7% (n = 22) were above average, indicating that the majority of participants possessed good dynamic postural control during multi-directional reaching tasks. Only 8.3% (n = 5) were classified as below average, highlighting that dynamic balance was relatively well developed among this athletic population compared to static balance.The Hexagon Agility Test, used to assess agility and coordination, showed that 16.7% (n = 10) of athletes performed at an excellent level, while 33.3% (n = 20) were above average. The largest proportion, 36.7% (n = 22), fell within the average category, suggesting that while many athletes possess acceptable agility, fewer demonstrate elite-level quickness and coordination. Additionally, 13.3% (n = 8) were below average, indicating room for improvement through targeted agility training.For the T-Test, which evaluates change of direction speed (COD), 23.3% of athletes (n = 14) achieved excellent performance, and 35% (n = 21) were above average. About 31.7% (n = 19) demonstrated average COD ability, while only 10% (n = 6) were classified as below average. This distribution suggests that most athletes in the study possessed reasonably good directional speed and movement efficiency, likely due to regular participation in sports requiring rapid directional changes.

DISCUSSION

The present observational study was designed to examine the interrelationship between static balance, dynamic balance, agility, and change of direction speed (CODS) in young athletes aged 12–18 years. A total of 60 recreational and competitive athletes from multiple sports were assessed using validated field-based tests, including the Stork Stand Test, Y-Balance Test, Hexagon Agility Test, and T-Test. The findings demonstrated that dynamic balance, particularly the posteromedial and posterolateral reach components of the Y-Balance Test, showed the strongest associations with both agility and COD performance. Static balance showed moderate but significant relationships with agility and CODS, while age demonstrated positive associations with dynamic balance and faster agility and COD performance. Higher BMI was associated with poorer balance and slower movement performance. Overall, the results indicate that balance—especially dynamic balance—plays a critical role in efficient multidirectional movement and neuromuscular performance during adolescence.

When these findings are critically compared with existing literature, strong agreement is observed with multiple contemporary studies that identify dynamic balance as a key determinant of agility and COD performance. Falces-Prieto et al. (2022) reported moderate correlations between dynamic balance-related hopping tasks and COD speed in youth football players, supporting the present finding that dynamic balance contributes significantly to efficient directional changes. Similarly, Wang et al. (2025), in a systematic review of basketball players, concluded that balance training—particularly dynamic balance—improves agility and stability more consistently than static balance training. These findings directly support the present study's observation that dynamic balance demonstrates stronger predictive value for agility and CODS than static balance.

The strong association found between posteromedial reach and COD performance is also supported by Chen et al. (2024), who demonstrated greater COD improvements when balance training was performed on unstable surfaces. Duchene et al. (2023) further reinforced this biomechanical relevance by showing that athletes with better neuromuscular control and core stability exhibit more efficient sidestepping mechanics and reduced joint loading during COD tasks. Collectively, these studies support the present thesis that dynamic, multi-directional stability is a critical neuromuscular prerequisite for effective agility and directional speed.

The significant correlation between agility and CODS observed in this study aligns with Falch et al. (2019) and Carvajal-Espinoza et al. (2023), who reported that multimodal physical training significantly improves COD ability, suggesting shared neuromuscular foundations between agility and COD. However, this finding must be interpreted critically in light of Morral-Yepes et al. (2023), who reported weak to moderate correlations between agility and COD tasks in semi-professional female football players and emphasized that agility and CODS are distinct constructs. The apparent contradiction may be explained by differences in participant age and task complexity. While Morral-Yepes et al. used reactive agility tasks requiring decision-making, the present study employed pre-planned agility and COD tests, where neuromuscular efficiency and balance likely play a greater role than perceptual-cognitive processing. Thus, rather than contradicting previous work, the present findings highlight developmental and methodological influences on agility–COD relationships.

Age-related improvements in dynamic balance, agility, and COD performance observed in this study are strongly supported by Živković et al. (2022) and Sariati et al. (2021), who demonstrated that biological maturation significantly influences neuromuscular performance variables. These studies support the present observation that older adolescents perform better due to improved coordination, strength, and movement efficiency. In contrast, static balance showed only a weak and non-significant association with age, which aligns with Liu et al. (2024), who reported that static and dynamic balance mature differently and that dynamic balance continues to develop with age and training exposure. This supports the interpretation that static balance reaches a plateau earlier, while dynamic balance remains more responsive during adolescence.

The strong association observed between posteromedial dynamic balance and COD performance ($r = -0.51$, $p < 0.001$), as well as between agility and COD ($r = 0.63$, $p < 0.001$), aligns with the systematic review and meta-analysis by Plisky et al. (2021), who reported that the Y-Balance Test is a reliable indicator of lower-limb dynamic control and can differentiate athletic performance levels. Similarly, the systematic review by Granacher and colleagues (2018) highlighted that balance training in children and adolescents significantly improves balance performance, supporting the present study's conclusion that balance—particularly dynamic balance—is a trainable and performance-relevant quality in youth athletes. Further support is provided by Brachman et al. (2017), whose systematic review concluded that balance training programs consistently improve postural control in athletes, reinforcing the idea that balance underpins efficient movement execution. The importance of agility and COD as neuromuscular skills is also supported by Sun et al. (2025), who, in their meta-analysis on speed, agility, and quickness (SAQ) training, reported significant improvements in agility-related outcomes, indirectly supporting the strong agility–COD relationship found in the present study. Additionally, Carvajal-Espinoza et al. (2023), in their review on change of direction performance, emphasized that COD ability is multifactorial and depends on strength, balance, coordination, and neuromuscular control, which directly supports the present finding that dynamic balance measures showed stronger correlations with COD than static balance. Evidence from youth-specific populations further supports these results, as Zheng et al. (2025) and Zhou et al. (2024), through their respective meta-analyses on plyometric training in adolescent soccer and basketball players, demonstrated significant improvements in balance, agility, and COD performance following neuromuscular-focused training. Moreover, the network meta-analysis by Chen et al. (2025) concluded that training interventions combining balance, strength, and power are most effective for improving COD in adolescent team-sport athletes, which supports the present study’s conclusion that balance, agility, and COD should not be trained in isolation. However, not all review-level evidence fully supports a universal relationship between balance measures and performance outcomes. Read et al. (2020) cautioned that anterior Y-Balance reach should not be used alone as a predictor of injury or performance, suggesting that balance–performance relationships may be task- and population-specific. This partially contrasts with the present findings, where anterior reach showed moderate but significant correlations with agility ($r = -0.44$, $p = 0.001$) and COD ($r = -0.38$, $p = 0.005$). Such differences may be explained by variations in age group, sport type, and outcome focus (injury risk versus performance). Overall, when critically reviewed alongside these major review and meta-analysis studies, the present findings strongly support the view that dynamic balance—especially in diagonal and lateral directions—is a key neuromuscular factor influencing agility and change of direction speed in young athletes, while also acknowledging that the strength of these relationships can vary depending on population characteristics and testing methods.

The negative influence of BMI on balance, agility, and COD performance observed in the present study is supported by Chaari et al. (2022) and Wang et al. (2025), who identified balance asymmetry and higher body mass as contributors to poorer movement efficiency and increased injury risk. However, Raya-González et al. (2020) reported no association between physical asymmetries and performance in elite academy football players, which contrasts with the present findings. This discrepancy may be attributed to differences in competitive level, as elite athletes may develop compensatory neuromuscular strategies that mitigate the impact of anthropometric variation, whereas youth athletes are still developing such adaptations. This highlights an important developmental distinction and reinforces the need for early neuromuscular training in younger populations.

The performance classification results further support the argument that regular sports participation alone does not guarantee optimal neuromuscular development. This observation is consistent with findings by Muehlbauer et al. (2021) and Schedler et al. (2022), who demonstrated that structured balance training produces consistent improvements regardless of training volume or frequency. The present study extends this evidence by showing that even in an active youth population, a substantial proportion of athletes demonstrate average or below-average balance and agility, emphasizing the need for targeted training interventions rather than reliance on sport-specific practice alone.

In critical synthesis, the present study supports the growing consensus that dynamic balance is a central determinant of agility and change of direction performance in young athletes, while static balance serves as a supportive but less performance-sensitive component. Although some discrepancies exist in the literature - particularly regarding the relationship between agility and COD and the influence of anthropometric factors - these differences can largely be explained by variations in age, maturity status, task demands, and competitive level. By examining static balance, dynamic balance, agility, and CODS collectively within the same cohort, this study contributes meaningful evidence to youth sports science and reinforces the need for integrated neuromuscular assessment and training models during adolescence.

CONCLUSION

This observational study was conducted to examine the relationship between static balance, dynamic balance, agility, and change of direction speed (CODS) in young athletes aged 12–18 years. Sixty recreational and competitive athletes from various sports were assessed using standardized field-based tests. The findings of this study clearly demonstrate that balance—particularly dynamic balance - is a key neuromuscular factor influencing athletic performance during adolescence.

The results showed that athletes with better dynamic balance, especially in the posteromedial and posterolateral directions of the Y-Balance Test, performed significantly better in agility and COD tasks. This indicates that the ability to control body position during movement, single-leg stability, and effective weight transfer are essential for fast and efficient directional changes. Static balance also showed a significant relationship with agility and COD performance, but its influence was weaker compared to dynamic balance. This suggests that static balance provides a basic foundation for postural control, whereas dynamic balance is more critical for sport-specific movements.

A strong relationship was observed between agility and change of direction speed, indicating that athletes who are more agile also tend to perform better in COD tasks. Age-related analysis showed that older athletes demonstrated superior dynamic balance, agility, and COD performance, likely due to improved neuromuscular coordination, strength, and movement efficiency with growth and maturation. Static balance showed minimal improvement with age, suggesting that dynamic movement control continues to develop throughout adolescence. Additionally, athletes with a higher BMI showed poorer balance, slower agility, and poorer COD performance, highlighting the influence of body composition on movement efficiency in youth athletes.

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