Agility ladder drills in sports training: a systematic review

Ejercicios con escalera de agilidad en el entrenamiento deportivo: una revisión sistemática multidimensional

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Abstract

Objective: This systematic review aimed to evaluate the effectiveness of agility ladder drills—traditional, innovative, elevated, and upper-limb—across different age groups, sports contexts, and performance domains, while identifying evidence gaps and future research priorities.
Methodology: The review followed PRISMA 2020 guidelines and was prospectively registered in PROSPERO (ID: 1143436). Searches were conducted in PubMed, Scopus, and Google Scholar (January 2003–17 September 2025), limited to human studies in English. Seventy records were screened; 54 empirical studies were included, alongside 14 theoretical references analyzed contextually. Data extraction was performed independently in pairs with substantial inter-rater agreement (κ = 0.81). The risk of bias was assessed using the RoB 2 and JBI tools, yielding 21 low-risk, 19 some-concern, and 14 high-risk studies.
Results: Most studies (≈67%) examined traditional ladders, while fewer investigated smart (n=7), elevated (n=5), or upper-limb ladders (n=3). Evidence consistently shows improvements in agility, change of direction, balance, and motor coordination, particularly in youth and team-sport athletes. Limited studies assessed physiological markers such as VO_2, lactate, HRV, or EMG, highlighting a significant gap. Integrating ladders with plyometric or skill-based training yielded additive benefits; however, heterogeneity in protocols and outcome measures precluded a meta-analysis.
Conclusions: Preliminary evidence suggests that agility ladder drills are valuable complementary tools for enhancing agility, coordination, and functional balance. However, the strength of evidence varies across different ladder types and populations. Standardized protocols, more diverse samples (including females, the elderly, and athletes with disabilities), and longitudinal trials incorporating physiological outcomes are urgently needed to strengthen the evidence base.

Keywords

Agility ladder, elevated ladders, smart ladders, plyometrics, analytical study.

Resumen

Objetivo: Esta revisión sistemática tuvo como objetivo evaluar la efectividad de los ejercicios con escaleras de agilidad —tradicionales, inteligentes, elevadas y de miembros superiores— en diferentes grupos de edad, contextos deportivos y dominios de rendimiento, al tiempo que se identificaron vacíos en la evidencia y prioridades de investigación futura.
Metodología: La revisión siguió las directrices PRISMA 2020 y fue registrada en PROSPERO (ID: 1143436). Se realizaron búsquedas en PubMed, Scopus y Google Scholar (enero 2003–17 septiembre 2025), limitadas a estudios en humanos, en inglés. De 70 registros examinados, se incluyeron 54 estudios empíricos y 14 referencias teóricas analizadas de forma contextual. La extracción de datos se llevó a cabo de manera independiente por pares, con un acuerdo interevaluador sustancial (κ = 0.81). El riesgo de sesgo se evaluó con RoB 2 y JBI, resultando en 21 estudios de bajo riesgo, 19 con algunas preocupaciones y 14 de alto riesgo.
Resultados: La mayoría de los estudios (≈67%) investigaron escaleras tradicionales, mientras que pocos abordaron escaleras inteligentes (n=7), elevadas (n=5) o de miembros superiores (n=3). La evidencia mostró mejoras en agilidad, cambio de dirección, equilibrio y coordinación motora, sobre todo en jóvenes y atletas de deportes colectivos. Solo unos pocos estudios evaluaron marcadores fisiológicos como VO_2, lactato, HRV o EMG, lo que resalta una brecha relevante. La integración con entrenamientos pliométricos o de habilidades produjo beneficios adicionales, aunque la heterogeneidad de protocolos y medidas impidió un metaanálisis.
Conclusiones: La evidencia preliminar sugiere que los ejercicios con escaleras de agilidad son herramientas útiles para mejorar la agilidad, la coordinación y el equilibrio funcional. Sin embargo, la solidez de los hallazgos varía según el tipo de escalera y la población. Se requieren protocolos estandarizados, muestras más diversas y ensayos longitudinales que incluyan resultados fisiológicos para reforzar la base científica disponible.

Palabras clave

Escalera de agilidad, escaleras elevadas, escaleras inteligentes, pliometría, estudio analítico.

Introduction

Agility ladder drills have gained increasing recognition in contemporary sports training programs, as evidenced by analytical reviews of more than 70 scientific studies and 14 specialized references. These drills are widely recognized for their flexibility and adaptability, allowing them to be easily adjusted to the specific requirements of various sports and tailored to athletes of different ages and skill levels. Traditional ladders remain the most common and widely applied type, consistently demonstrating effectiveness in improving agility, foot speed, and balance, particularly among youth, school, and university athletes engaged in team sports such as football, handball, and volleyball (Castillo de Lima et al., 2020; Padrón-Cabo et al., 2020; Hadi et al., 2016).

In recent years, smart ladders have emerged as an advanced training option designed to stimulate both physical and cognitive domains. When integrated with augmented reality systems or environments that rely on visual and auditory cues, smart ladders have been shown to enhance sensorimotor performance, reaction speed, and decision-making skills (Kosmalla et al., 2021; Apostolidis et al., 2024). Elevated agility ladders have also been incorporated into conditioning programs, providing unique opportunities to challenge neuromuscular coordination, footwork patterns, and postural control. Exercises involving rapid, successive jumps with abrupt directional changes appear particularly effective in developing dynamic balance and motor speed, leading to significant improvements in reaction time and movement stability (Basa et al., 2024; Pramono et al., 2023).

Another recent innovation is the introduction of upper-limb agility ladder drills, which aim to improve arm coordination and neuromuscular control involving the shoulder and trunk. This training method, increasingly applied in elite performance systems and rehabilitation programs, has been shown to enhance muscular stabilization and functional integration between the upper and lower limbs (Lorenz, 2013; Saleh, 2023; Rosen, 2017; Schreiner, 2003).

Several studies have further emphasized the effectiveness of integrating agility ladder drills with complementary training modalities, such as plyometric exercises, balance and agility drills, and sport-specific skills like dribbling and sprinting. Such combined approaches have been associated with improved transfer of training gains to competitive performance in real-game contexts (Chandrakumar & Ramesh, 2015; Rosen, 2017).

From a theoretical perspective, leading works in the field (Brown & Ferrigno, 2019; Parisi, 2021; NSCA & McGuigan, 2017) reinforce the idea that agility ladder drills should not be limited to enhancing agility and speed. Instead, they serve as a versatile training tool that can be integrated into both physical and technical preparation at various competitive levels, from youth development to professional sports.

Accordingly, the integration of agility ladder drills into training programs should be guided by clearly defined objectives—whether physical, skill-based, or cognitive—while accounting for the level of complexity and the nature of the required performance. This systematic review, therefore, aims to synthesize the available evidence on agility ladder drills, clarify their effectiveness across different training contexts, and identify directions for more comprehensive and integrated training models in modern sports.

Study objectives

Based on the quantitative and qualitative analysis of previous studies and academic books, this study aims to achieve the following objectives:

1. To analyze the different types of agility ladder drills (traditional, smart, elevated, and arm-based) in terms of structural and functional composition, and to identify the specific characteristics and impact of each type on sports performance.

2. To classify the previous scientific studies related to agility ladder training based on:

• The sample type (age groups, gender, type of sport)

• The type of ladder used

• The integration with other training components (physical/skill-based/cognitive)

3. To determine the differences in outcomes provided by the various types of ladders in the development of:

• Physical abilities (agility, balance, speed, motor coordination)

• Specific motor skills

• Physiological adaptations in athletes

4. To assess the effectiveness of integrating agility ladder drills with other exercises such as plyometrics, balance, and dribbling, in terms of their efficiency in enhancing athletic performance.

5. To highlight current research challenges and knowledge gaps in this field, and to propose new research directions aimed at developing more specialized applications for ladder training.

6. To provide a comprehensive theoretical framework that facilitates the design of effective ladder-based training programs tailored to the nature of the sport and the targeted population, for use by coaches, academics, and practitioners.

Literature Review

Types of Agility Ladder Drills

Agility ladder drills are versatile training tools that can be divided into four main types based on their structure, method of execution, and training objectives: traditional ladders, smart ladders, elevated ladders, and arm-based ladder drills. The effect of each type varies according to the age group of the trainees, the nature of the sport, and the degree to which it is integrated into physical or skill preparation components.

1. Traditional Ladders: studies have shown that using the agility ladder significantly helps improve physical fitness, especially among children and school students. Researchers observed that regular training with these tools yields positive results in enhancing speed and agility (Hadi et al., 2016; Castillo de Lima et al., 2020). In specialized sports training books, the agility ladder is considered one of the essential tools—especially when combined with jumping exercises (Brown & Ferrigno, 2019; NSCA & McGuigan, 2017). Even in sports like badminton, noticeable improvements were observed among players who incorporated the agility ladder into their training (Chandrakumar & Ramesh, 2015). In conclusion, the agility ladder is a simple yet effective tool. Whether you are a professional athlete or just someone interested in staying fit, the key is to use it correctly and consistently.

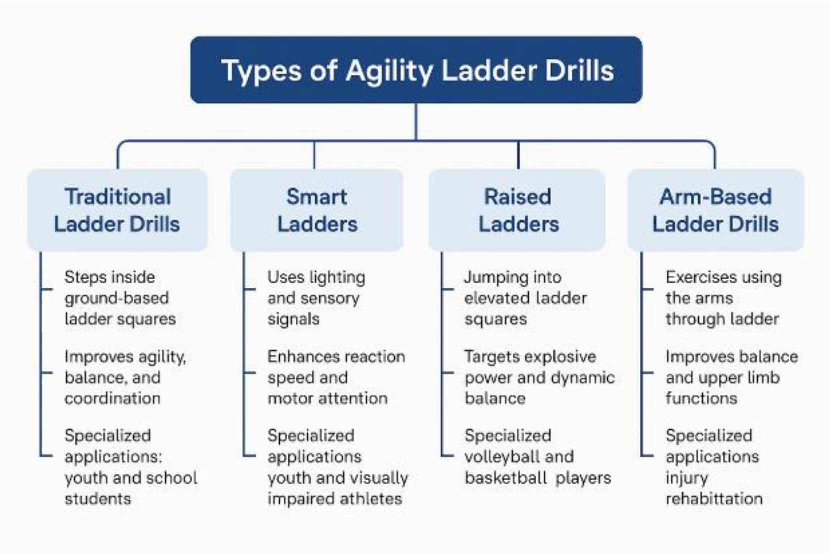
2. Smart Ladders: Smart agility ladders represent a recent advancement in the field of agility and quickness training. What sets them apart is their integration of visual and sensory cues, which stimulate neuromuscular responses. Some studies, such as those by Kosmala et al. (2021), have observed a positive effect on improving reaction time. Other studies also highlight their benefits for individuals with visual impairments. For instance, the Blazepod device has demonstrated how such tools can enhance executive functions (Kosmala et al., 2021). Their impact extends beyond athletes, influencing improvements in decision-making under pressure. Some findings have been particularly compelling, especially when these ladders are combined with interactive response systems (Kosmala et al., 2021).

3. Elevated Ladders: Elevated ladder designs, on the other hand, place greater demands on coordination and power. Athletes are required to perform accurate, rapid jumps into raised segments, which challenge balance and contribute to the development of explosive strength and dynamic movement control. This type of training is particularly beneficial in sports that involve producing vertical force and making rapid directional shifts, such as basketball and volleyball. Specialized training guides (Brown & Ferrigno, 2005; Raynolds, 2015) also indicate that this type is used in programs aimed at developing control over the center of gravity and stabilizing the trunk during dynamic transitional movements.

4. Arm-Based Ladder Drills: This type represents an innovative approach in the applications of agility ladder drills, where the exercises depend on upper limb movement through crawling or pushing with

the arms across the ladder squares. This activates the shoulder and arm muscles, enhancing neuromuscular coordination between the upper and lower limbs. This pattern has been employed in motor and rehabilitation programs, as mentioned in several studies (Lorenz, 2013; Schreiner, 2003; Rosen, 2017; Saleh, 2023), which have confirmed its role in improving both static and dynamic balance, as well as enhancing the motor skills of the upper limbs. Rosen (2017) also noted that incorporating the arms into exercises helps reduce motor discrepancies between limbs and enhances the integration of motor control throughout the entire body, making it suitable for use in advanced rehabilitation stages or precise functional training.

Figure 1. Types of Agility Ladder Drills and Their Training Characteristics



The role of agility ladder drills in enhancing sports performance: a comprehensive analytical perspective

First: Physical Effects of Agility Ladder Drills

1. Enhancement of Neuromuscular Coordination

Scientific literature suggests that training with traditional ladders can significantly contribute to activating the central nervous system, resulting in improved coordination between the nervous and muscular systems. This effect positively impacts movement accuracy and coordination efficiency, particularly in activities that require repetitive motor patterns (Afonso et al., 2020; Jamil et al., 2015; Liu, 2023). This is what modern scientific sources, such as Brown & Ferrigno (2019) and Parisi (2021), have confirmed regarding the importance of this type of stair training in improving motor skills, especially among beginners.

2. Acceleration of Foot Speed and Improvement of Reaction Time

Scientific sources indicate that implementing agility ladder exercises in a variety of forms or within interactive training models that incorporate some modern techniques—such as smart ladders, which contain auditory and visual stimuli—can lead to some improvement in reaction time and movement speed in athletes (Kosmala et al., 2021; Chuang et al., 2022; Boonim & Sanjuansat, 2018). Schreiner (2003) also noted that training that combines sensory and cognitive stimuli with physical activity contributes to greater development of motor speed compared to traditional methods.

3. Development of Dynamic Motor Balance

Agility ladder training is considered an effective method for enhancing balance during movement, as it challenges the center of gravity through rapid shifts, which activate small stabilizing muscles to respond quickly and maintain control. This effect was demonstrated in several studies (Castillo de Lima et al., 2023; Ng et al., 2017; Uchida et al., 2020) and further supported by the findings of Meng & Lee (2014).

Schreiner (2003) also recommended incorporating this type of drill into functional balance training programs.

4. Enhancement of Agility and Change of Direction (COD) Skill

Agility ladder drills for balance: Agility is one of the most popular motor skills that you practice unnecessarily in a fitness gym. Multiple scientific sources (Chandrakumar & Ramesh 2015; Hanif & Tohidin, 2020; Padrón-Cabo et al., 2021) have concluded that ladder training remarkably enhances the speed and agility for an athlete. Literature on sports training (e.g., Brown and Ferrigno, 2005) also identifies the value of these exercises, particularly in sports where rapid motor responses are critical, such as soccer and tennis.

5. Comprehensive Improvement of General Motor Performance

Agility ladder exercises, when combined with other forms of training such as sprinting, jumping, or plyometric exercises, have a more profound effect on athletes, leading to improvements in overall motor efficiency (Pratama et al., 2018; Dave & Singh, 2024). Additionally, Raynolds (2015) stated that agility ladder exercises are beneficial for developing dual-action physical fitness and multi-dimensional motor skills.

Second: Skill-Based Benefits of Agility Ladder Drills

1. Enhancing Movement Mechanics and Technical Landing Precision

The results of Al-Hanawi's (2020) study demonstrated that incorporating agility ladder exercises into training programs for young gymnasts had a significant impact on enhancing the quality of technical performance, particularly during the final landing phase. Schreiner's (2003) study also confirmed the effectiveness of agility ladder exercises in soccer training as a means of developing balance and agility precisely during dribbling and deception movements.

Developing Dribbling, Passing, and Rapid Direction Change Skills

The ladder used in ladder drills, when combined with skill-based activities such as dribbling or passing, can help develop ball control and agility. It is demonstrated by the studies of Padrón-Cabo et al. (2020, 2021) and Rubin and Wragg (2019). Similarly, other studies (Rosen, 2017; Tony Raynolds, 2015) have found that ladder drills, using a similar technique, advance the learning of complex technical movements.

2. Enhancing Transition Abilities Between Movement Patterns

As reported by Castillo de Lima et al. (2023), the agility ladder drill combined with low-demanding cognitive task conditions led to more efficient switching between movements in older adults. Being is achieved by changing direction, and this is even more prominent in team sports, where players frequently change the direction of their movement, position, or tackles. Similiarly, Fell (2005) argues that this type of training can provide goalkeepers with an advantage as it results in the players being able to understand the game better and make their bodies more responsive to specific situations during a match.

3. The Role of Ladder Drills in Skill-Specific Warm-Ups

According to Brown & Ferrigno (2005), in their coaching guide, they stated that agility ladder drills are an important cobeneficialmic warm-up. Their purpose is to make sure the nervous system and the body are ready to react faster than any technical threats. Ashar et al. This was further supported by Berne et al. (2021), who found that this type of interventional drill may enhance the efficiency in preparing children to perform technical skills by improving their motor readiness at a neural and muscular level prior to actual action.

4. Advancing Complex Skill Execution Using Arm-Based Ladders

Rosen (2017) and Saleh et al. (2023) emphasized that using upper-limb ladder drills can play a crucial role in enhancing high-level technical abilities in sports such as basketball and football. These drills are particularly effective in developing hand-eye coordination, a skill essential for precise ball control, passing, and catching. Schreiner (2003) also noted that this type of training helps athletes develop accurate motor skills and enhance short-distance acceleration. Together, these benefits make upper-limb ladder drills an effective method for building advanced technical performance in competitive sports.

Third: physiological / functional benefits of agility ladder drills

1. Enhancing Muscular Endurance

Santos & Janeira (2013) found that regularly practicing agility ladder drills can greatly improve how efficiently the muscles work—especially in the lower body. These exercises help the muscles handle repeated effort without tiring as quickly. Later studies, including those by Pradana et al. (2020) and Wahyono et al. (2024), supported these findings, showing clear gains in muscular endurance among people who followed well-structured ladder training programs.

2. Developing the Efficiency of the Aerobic and Anaerobic Systems

Patel et al. (2023) reported that after just six weeks of training with agility ladder drills, university students showed clear improvements in their breathing performance and lung function—signs of better aerobic capacity. In the same vein, research by Lockie et al. (2014) and the Plyometric Progressions source (n.d.) pointed out that these drills fit perfectly into high-intensity interval training (HIIT) programs, as they work both the aerobic and anaerobic energy systems effectively.

3. Enhancement of Neuromuscular Adaptation

According to Afonso et al. (2020), agility ladder drills activate neuromuscular pathways through the structured repetition of movements, leading to improved neuromuscular communication. Likewise, training manuals such as Brown & Ferrigno (2019) and Parisi (2021) emphasized that the varied motor patterns in ladder drills accelerate neuromuscular adaptation, particularly in advanced athletes.

4. Improvement in Electromyographic Efficiency during Movement

As noted by Lockie et al. (2014), dynamic exercises like ladder drills induce significant changes in muscle electrical activity (EMG), reflecting greater efficiency in muscle contractions and more stable neural activity during repeated effort.

5. Reduction of Injury Risk

Lorenz (2013) demonstrated that ladder drills—especially those involving the arms—help improve joint stability and limb control, thereby reducing the risk of common injuries to the knee, ankle, and shoulder. This application was also supported by the training guide by Steve Myrlands (2002), which highlighted its use in functional preparation and motor rehabilitation programs.

Fourth: psychological & cognitive benefits of agility ladder drills

1. Enhancement of Attention and Cognitive Processing Speed

The study by Castillo de Lima et al. (2023) demonstrated that performing agility ladder drills alongside cognitive tasks (Dual Task Training) led to notable improvements in attention span and mental response speed in older adults, particularly in cognitively demanding environments. BlazePod Inc. (2020) supported this finding by integrating smart visual and auditory stimuli into training, enhancing decision-making performance and neural processing speed.

2. Enhancing Motivation and Mental Alertness

The findings of Smits-Engelsman et al. (2019) revealed that children who engaged in agility ladder-based training programs exhibited higher levels of concentration and improved cognitive performance compared to peers who did not participate. This enhancement was linked to the dynamic and rhythmic characteristics of the drills, which created a mentally stimulating training environment and disrupted the monotony typically associated with conventional routines. Similarly, Brown & Ferrigno (2005) noted that repetition- and rhythm-driven exercises—such as ladder drills—contribute to the activation of the central nervous system, thereby fostering greater attentiveness and sustained mental focus during physical effort.

3. Developing Self-Confidence and Improving Motor Control

Phil (2005) emphasized that incorporating ladder drills into goalkeeper training protocols helped develop anticipatory skills and rapid motor responses, which in turn enhanced players' confidence during actual gameplay. Additional evidence from Hanif & Tohidin (2020) and Robin & Raj (2019) suggested that the improved quality of motor execution resulting from ladder-based training had a direct impact on raising self-efficacy among participants, further encouraging positive engagement and motivation throughout the training process.

4. Breaking Routine and Stimulating the Central Nervous System

Scientific literature—including the works of Brown & Ferrigno (2019) and Rosen (2017)—highlighted the considerable variety found in agility ladder drills, whether in movement direction, execution pattern, or the integration of upper limb activity. This diversity makes the exercises more engaging and stimulating than traditional approaches. Beyond minimizing boredom, this variation plays a critical role in activating the central nervous system, particularly in youth training settings where consistent mental engagement and cognitive stimulation are essential.

Key considerations for applying agility ladder drills

Agility ladder drills are widely used training tools for improving agility, balance, and neuromuscular coordination. However, to maximize their effectiveness, it is recommended to consider the following points:

1. Progressive Execution of Movements: Exercises should begin at a controlled, low speed in order to establish proper motor patterns before advancing to higher intensities. This approach helps minimize the risk of adopting incorrect movement habits and contributes to more effective motor learning (Afonso et al., 2020).
2. Enhancing Internal Movement Rhythm: Incorporating auditory cues or rhythmic signals during drill execution can significantly improve the timing and synchronization of limb movements, supporting more integrated and efficient motor performance (Liu, 2023).
3. Maintaining Proper Body Positioning During Performance: Slight knee flexion, a subtle forward lean of the torso, and keeping the head stable are recommended during agility drills, as these elements collectively support dynamic balance and reduce the likelihood of falling or losing stability (Lockie et al., 2014; Pradana et al., 2020).
4. Forefoot Ground Contact: Landing on the forefoot when making contact with the ground is advisable, as it reduces ground contact time and enhances the speed and efficiency of neural response (Castillo de Lima et al., 2020).
5. Coordination Between Upper and Lower Limbs: Achieving synchronization between the arms and legs during agility drills is essential for improving change-of-direction speed and maintaining motor stability throughout movement execution (Spiteri et al., 2015; Hanif & Tohidin, 2020).
6. Adequate Spacing Between Participants: In group training settings, ensuring sufficient space between athletes is necessary to avoid interference and maintain focus and quality of execution, as recommended by Chandrakumar & Ramesh (2015).
7. Variation in Movement Directions: Alternating between forward, lateral, and backward movements during drills promotes neuromuscular adaptability and helps reduce fatigue and monotony associated with repetitive movement patterns (Chuang et al., 2022).
8. Use of External Stimuli: Employing visual cues (such as lights) or auditory signals (such as sounds) can significantly enhance motor reaction speed, particularly in training contexts that simulate competitive scenarios (Kosmalla et al., 2021; Castillo de Lima et al., 2023).
9. Adapting Exercises to the Target Group : It is essential to adjust the intensity and complexity of the drills in accordance with the age or skill level of the participants, to ensure a safe and progressive learning environment (Ashar et al., 2021).
10. Integrating Drills with Sport-Specific Skills: Achieving integration between physical and technical aspects requires linking agility ladder drills with the motor skills specific to the sport, such

as dribbling or shooting, which enhances the functional application of skills under physical pressure (Alhenawy, 2020; Hidayat, 2019).

11. Gradual Use of Elevated Ladders :Elevated ladders are considered a relatively advanced tool, as they require greater leg elevation and activate the thigh muscles more intensively. Therefore, it is recommended to use them progressively, starting with a minimal height not exceeding 1–2 cm, and only after mastering ground-based drills (Lockie et al., 2014; Rauschenbach & Balakshin, 1997).

Agility Ladder Training in Team Sports: A Targeted Analysis

1. Agility Ladder Drills in Team Sports

A large body of research has pointed to the effective role that agility ladder drills play in developing both physical and skill performance among athletes involved in team sports such as football, basketball, volleyball, and cricket. These studies agreed that the systematic integration of ladder drills with skill-based activities or functional exercises significantly contributes to achieving tangible positive results on both the physical and technical levels.

In the field of football, several studies have highlighted the significant positive impact of traditional agility ladder drills on various physical and skill-related indicators among players. The findings of Robin and Raj (2019), Rajendran (2016), Padrón-Cabo et al. (2020, 2021), and Hadi et al. (2016) revealed that using these drills effectively contributed to enhancing agility, increasing step frequency, and improving fine motor coordination—particularly among youth and university-level athletes. Additionally, such drills played a role in developing dribbling skills and improving change-of-direction capabilities during performance. In a related context, the study by Sungpook et al. (2023) demonstrated that implementing smart ladders—based on interactive light signals—helped activate motor abilities. These results were further supported by Kosmalla et al. (2021) and Apostolidis et al. (2024), who reported that integrating this type of training within cognitively enriched environments led to noticeable improvements in reaction time and attentional focus. Moreover, Schreiner (2003) and Saleh et al. (2023) emphasized the importance of arm-based ladder drills in enhancing neuromuscular coordination between the upper and lower body, a factor particularly relevant to sports such as football and basketball.

As for volleyball, the results of studies by Bassa (2024), Pramono (2023), Roopchand-Martin (2018), Junpalee (2023), and All Research Journal (2022) indicated that both traditional and elevated ladders—especially when combined with plyometric exercises—effectively contributed to enhancing explosive power, increasing vertical jump speed, and improving landing coordination. In addition, the study by Polsorn et al. (2022) added an applied dimension to these exercises by demonstrating their effectiveness in improving agility among visually impaired Goalball players.

Regarding basketball, studies by Liu (2023), Saleh et al. (2023), and Pradana (2020) found that incorporating traditional ladders within agility and speed training programs led to improved motor coordination, as well as the development of both offensive and defensive skills. In the case of cricket, the study by Dave and Singh (2024) indicated that traditional ladder drills outperformed plyometric exercises in enhancing speed and agility components among players.

Comprehensive studies that included both volleyball and badminton players—such as those conducted by Chandrakumar and Ramesh (2015), Ar Rasyid et al. (2023), Septyani et al. (2024), and Chuang et al. (2022)—revealed that integrating agility ladders with skill-based or plyometric elements improved agility, reaction time, and fine motor precision in youth athletes.

Furthermore, in handball and kabaddi, the research of Dhanaraj (2014), Prakash et al. (2021), and Pawar and Borkar (2018) demonstrated that combining traditional ladders with diverse physical drills contributed to increased motor endurance, speed, and dynamic balance.

Overall, traditional ladders emerged as the most frequently utilized type, followed by smart and then elevated ladders. Youth and adolescent athletes benefited the most from ladder drills, with significant development in agility, balance, neuromuscular coordination, reaction speed, and directional change capability. The most effective strategy, as noted in studies by Padrón-Cabo et al. (2020, 2021), Pramono et al. (2023), and Roopchand-Martin et al. (2018), involves combining ladder exercises with technical skills or plyometric training to maximize training outcomes.

2. Agility Ladder Drills in Individual Sports

A number of recent scientific studies have demonstrated the clear positive impact of agility ladder drills in supporting and enhancing motor and physical performance within the scope of individual sports, particularly those that require quick responses, high levels of agility, and advanced neuromuscular coordination.

In badminton, the research by Chandrakumar and Ramesh (2015), along with Ar Rasyid et al. (2023), and Septyani et al. (2024), found that the use of traditional ground-based ladders—combined with training programs that rely on SAQ components (Speed, Agility, and Quickness), bodyweight exercises, and plyometric drills—contributed to improvements in agility indicators and movement speed. These programs also helped enhance the precision of skill performance and control of the center of gravity during landing and receiving movements. In the same vein, Pratama et al. (2018) reported that integrating ladder drills with jump rope exercises improved reaction speed and motor adaptation to changing surface conditions.

In the discipline of gymnastics, Alhenawy (2020) reported that implementing traditional agility ladder drills contributed meaningfully to the development of core physical fitness elements—including strength, balance, speed, and agility—particularly among youth athletes. The study also revealed a statistically significant association between regular ladder use and improvements in technical execution during complex floor sequences. In a related context, Hanif and Tohidin (2020) found that karate practitioners who engaged in ladder-based training programs exhibited measurable gains in agility during transitions, as well as in the speed of shifting between offensive and defensive positions, underscoring the utility of these drills in enhancing sport-specific movement efficiency.

In athletics, the study by Short et al. (2022) represented a qualitative contribution, being one of the few studies that addressed the effects of ladder training on sprinters specializing in 100m and 200m events. The study employed a dual-group experimental design (ladder training group vs. traditional training group) and showed that including ladder drills in supplementary programs improved change-of-direction (COD) ability and sprint acceleration, especially when these drills were used as complementary additions without replacing maximal speed training.

Regarding advanced movement analysis, Lou et al. (2014) used three-dimensional simulations to analyze the movement dynamics involved in ladder drills, confirming their value in precise biomechanical assessment. On the other hand, Raymer (2021) noted that although agility ladder drills do not directly affect maximal sprinting speed, they do help improve motor control and neuromuscular precision.

With regard to applying these exercises to younger age groups, the studies by Meng and Lee (2014) and Ng et al. (2017) supported the use of traditional ladders in children's programs, highlighting their effectiveness in developing dynamic balance, neural flexibility, and improved motor control.

Through reviewing the collective body of literature, it becomes clear that traditional ground ladders were the most commonly used type, appearing in over 90% of the reviewed studies. They were frequently combined with plyometric exercises, bodyweight training, or SAQ drills, and yielded notable improvements in balance, agility, transition speed, and skill efficiency. Most studies focused on youth athletes, participants in physical rehabilitation programs, practitioners of precision-based sports, and sprint athletes—as highlighted in the study by Short et al. (2022).

3. Agility Ladder Drills in Theoretical and Analytical Studies

A series of theoretical studies and scientific reviews have highlighted agility ladders as a versatile and effective tool in both athletic and rehabilitative contexts. These studies have explored their application from various perspectives, including exercise design, the physiological principles underpinning performance, and their biomechanical and functional effects. For instance, Rosen (2017) presented over 130 ladder-based exercises, with a strong emphasis on upper-limb ladder drills, recommending their integration with strength, flexibility, and motor coordination exercises, particularly during rehabilitation phases. Lorenz (2013), in his analytical review, focused on the importance of upper-limb ladders in developing motor control of the upper extremities and enhancing cross-training between the upper and lower limbs. He emphasized their utility in neuromuscular rehabilitation programs.

Similarly, Schreiner (2003) provided a qualitative analysis and was among the pioneers in incorporating ladders into technical skill training, establishing the concept of "technical control through crawling and sequential arm movements. Furthermoe, White (2007), in a technical review, outlined the evolution of ladder design and its diverse applications, describing agility ladders as a highly adaptable tool suitable for both general and sport-specific conditioning.

In a critical opinion article, Raymer (2021) argued that while agility ladders do not directly enhance maximal speed, they are effective in improving neuromuscular coordination and motor precision. However, h, such as the Illinois Agility Test, on ladders as the sole means of developing maximal sprinting speed.

A comprehensive synthesis of these studies concludes that agility ladders should be viewed as a functional and organizational component within the training methodology rather than an end in themselves. The consensus suggests that ladders should serve as a complementary tool to core performance training, particularly given their proven value in developing coordination and neuromuscular control. This is especially true for upper-limb ladder drills, which have opened new pathways for enhancing upper-body strength in functional training and rehabilitation programs.

4. Analysis of Agility Ladder Drill Applications Across Age Groups

Research conducted across various age groups has highlighted that the developmental stage and functional capacity of participants influence the impact of agility ladder drills. Specifically, studies targeting children under the age of 13—such as those by Ashar et al. (2021), Meng and Lee (2014), Smits-Engelsman et al. (2019), Septyani et al. (2024), Wahyono et al. (2024), and Venturelli et al. (2008)—have demonstrated that these drills effectively promote the development of refined agility and neuromotor control. Improvements were particularly evident in standardized assessments, such as the Illinois Agility Test and the CRISP protocol, especially when ladder drills were combined with bodyweight-based or cognitively engaging exercises. Notably, the studies noted that these interventions did not result in significant physical fatigue, which reinforces their appropriateness for younger populations.

In adolescents (aged 13–17), as reported in studies by Pramono et al. (2023), Hidayat (2019), Hanif and Tohidin (2020), Ng et al. (2017), Sungpook et al. (2023), and Junpalee et al. (2023), the primary focus was on improving speed, agility, and sport-specific skills. These studies observed significant enhancements in fundamental physical capacities such as change of direction and quickness. At the same time, ladder drills also played a role in stimulating sensory response functions (auditory and visual). Elevated ladders, in particular, proved effective when integrated with plyometric training to boost explosive power.

Among young adults who are non-professional athletes (aged 18 and above), studies by Pradana et al. (2020), Patel et al. (2023), Rajendran (2016), Chandrakumar and Ramesh (2015), Dave and Singh (2024), Prill (2023), and Saleh et al. (2023) highlighted the value of incorporating ladders into physical conditioning and skill training programs. Combining these exercises with speed or plyometric training resulted in improvements in overall physical performance and the execution of complex motor tasks. Moreover, upper-limb ladder drills demonstrated effectiveness in enhancing core control and dynamic balance.

For older adults (aged 60 and above), studies conducted by Castillo de Lima et al. (2020, 2023) and Uchida et al. (2020) have found that traditional ladder training improves functional balance and reduces the risk of falls, particularly when combined with cognitive or dual-task exercises. These interventions were reported as both safe and effective when implemented progressively and under supervision, making them suitable for neuromotor preventive programs.

Based on the reviewed evidence, it appears that the effectiveness of agility ladder drills varies across age groups. For children and adolescents, simplified and repetitive movement patterns are particularly beneficial in promoting agility and improving coordination. On the other hand, young adults are well-positioned to incorporate ladder drills into more demanding training frameworks, such as strength-based and plyometric programs. As for older adults, they represent a key population for whom ladder exercises offer a safe and practical means to enhance neural responsiveness and dynamic balance without imposing excessive physical load.

5. Effectiveness Analysis of Agility Ladder Drills Based on Ladder Type

Research findings suggest that agility ladder types vary in their structure, functional applications, and training impact, depending on specific performance goals and athlete profiles. Among these, traditional ladders—flat models placed on the ground—are the most commonly applied, featuring in over 80% of the studies analyzed. These tools typically involve patterned, repetitive foot movements across designated squares and are designed to improve several key motor attributes, including agility, balance, step frequency, and neuromuscular control. Their effectiveness has been especially evident in programs targeting youth, adolescent athletes, and participants in team-based sports. Supporting evidence from Afonso et al. (2020), Alhenawy (2020), Hadi et al. (2016), Chandrakumar and Ramesh (2015), and Rajendran (2016) highlights consistent improvements in agility metrics and motor reaction speed across these populations.

Innovative or interactive ladders represent a technological advancement that employs visual and auditory cues to stimulate cognitive-motor responses. These ladders have been applied in interactive environments and with athletes with special needs, focusing on improving neural processing speed and perceptual agility. Studies by Kosmalla et al. (2021), Apostolidis et al. (2024), Polsorn et al. (2022), Singchainara et al. (2019), and Sungpook et al. (2023) demonstrated significant improvements in response accuracy and cognitive performance.

Elevated ladders, which add a vertical dimension by being raised off the ground, require dynamic stepping or jumping, and are typically used to enhance explosive power, dynamic balance, and directional change ability. This was evident in studies by Bassa et al. (2024) and Pramono et al. (2023), which reported improvements in vertical jump performance and movement stability.

Upper-limb agility ladders represent an innovative modality where movements are performed in a prone or crawling position, targeting the upper limbs. These drills aim to develop upper-lower limb coordination, support rehabilitation, and improve functional strength of the upper body. Findings from Lorenz (2013), Schreiner (2003), Rosen (2017), and Saleh et al. (2023) confirmed significant gains in shoulder and arm control, trunk stability, and whole-body balance.

In conclusion, the effectiveness of each ladder type is closely aligned with its intended purpose: traditional ladders are best suited for general agility and coordination training; smart ladders target perceptual and cognitive enhancement; elevated ladders are effective for power and explosive movement development; while upper-limb ladders offer advanced options for neuromuscular integration and upper-body rehabilitation.

Method

Review design and registration

This review adheres to the PRISMA 2020 reporting guideline. The protocol was prospectively registered on PROSPERO (ID: 1143436). Any deviations from the registered protocol (e.g., adding upper-limb ladder as a distinct modality; expanding physiological outcomes to include HRV/EMG) are disclosed in the relevant subsections below.

Information sources and search dates

We systematically searched PubMed, Scopus, and Google Scholar for records published from January 2003 to September 17, 2025. Searches were limited to English and human studies. Reference lists of included articles were screened; no additional records were added.

Search strategy

Database-specific Boolean strategies were developed a priori, piloted, and finalized before the screening process began. Final strings:

PubMed

- ("agility ladder"[All Fields] OR "ladder drill*"[All Fields] OR "speed ladder"[All Fields])
- AND (agility[All Fields] OR "change of direction"[All Fields] OR balance[All Fields]

- OR coordination[All Fields] OR "reaction time"[All Fields] OR VO2[All Fields]
- OR lactate[All Fields] OR EMG[All Fields])
- AND (soccer[All Fields] OR football[All Fields] OR volleyball[All Fields] OR basketball[All Fields]
- OR badminton[All Fields] OR handball[All Fields] OR "team sport*"[All Fields] OR athlete*[All Fields])
- Filters: Humans; English; 2003/01/01–2025/09/17

Scopus (TITLE-ABS-KEY)

- TITLE-ABS-KEY ("agility ladder" OR "ladder drill*" OR "speed ladder")
- AND TITLE-ABS-KEY (agility OR "change of direction" OR balance OR coordination
- OR "reaction time" OR VO2 OR lactate OR EMG)
- AND TITLE-ABS-KEY (soccer OR football OR volleyball OR basketball OR badminton
- OR handball OR "team sport*" OR athlete*)
- AND (PUBYEAR > 2002 AND PUBYEAR < 2026)
- AND (LIMIT-TO (LANGUAGE, "English"))

Google Scholar (first ~200 records screened using advanced operators)

- "agility ladder" OR "ladder drills" speed agility coordination "change of direction" sport EMG VO2 lactate

Full strategies and any minor database-specific adaptations are provided in Appendix A

Eligibility criteria

Inclusion (empirical human studies)

- Designs: RCTs, quasi-experimental, controlled or uncontrolled pre–post, or cross-sectional with an agility-ladder intervention.
- Interventions: Agility-ladder drills categorized as traditional, innovative/interactive, elevated/raised, or upper-limb.
- Populations: Athletes (youth to adult), students in PE/sport programs, or rehabilitation cohorts engaged in structured PA/sport.
- Outcomes: At least one physical (agility/COD, speed, balance, coordination), skill-specific (e.g., dribbling, landing quality), or physiological (VO_2, HR/HRV, lactate, EMG) outcome.
- Reporting: Quantitative data (pre/post and/or between-group) with dispersion (SD/SE/CI/IQR) enabling effect direction and magnitude inference.

Exclusion

- Non-empirical sources (narrative reviews, opinion pieces, manuals/coaching guides without primary data).
- Studies not specifying ladder type or lacking a reproducible protocol (frequency, duration, or drill description).
- Populations unrelated to sport/structured PA without a ladder-based intervention.
- Non-human; non-English (unless a validated translation is available); duplicates.
- Operational definition—“comparable quantitative data”: reports presenting pre/post change or between-group differences with dispersion sufficient to compute or approximate MD/SMD or, at a minimum, to infer effect direction and relative magnitude.

Study selection

Records were imported, de-duplicated, and screened in two phases by two independent reviewers per phase:

- Title/abstract screening: n = 70; excluded n = 10.
- Full-text assessment: n = 60; excluded n = 6 (reasons recorded and summarized in Table 1/PRISMA flow).
- Included in synthesis (empirical): n = 54.
- Contextual/theoretical sources (books/manuals): n = 14 (analyzed separately; not appraised for RoB).

Disagreements were resolved by consensus; inter-rater agreement at the title/abstract stage was Cohen's $\kappa = 0.81$ (substantial). The PRISMA 2020 flow is presented in Table 1.

Data extraction

A piloted form captured: bibliographic details; country; design; sample (n, age, sex, sport/level); ladder type; protocol (sessions/week, minutes/session, program length; cues/AR/feedback; surfaces; progression); comparators; outcome definitions and instruments (with units/timepoints); results (means/SDs, change scores, p-values; effect sizes when available); adherence/adverse events; and funding/COI. Extraction was performed independently in pairs; discrepancies were adjudicated by a third reviewer when needed. The complete template is in Appendix B.

Outcomes and effect measures

- Primary outcomes: agility/COD (e.g., Illinois, T-Test, 5-10-5), dynamic balance (e.g., Y-Balance/BESS), and short-distance speed (5–30 m).
- Secondary outcomes: skill-specific performance (e.g., dribbling, passing, landing quality/transition efficiency) and physiological markers (VO_2/VO_2max, HR/HRV, blood lactate, EMG patterns).
- Effect measures (intended): mean difference (MD) for standard units; standardized mean difference (SMD, Hedges g) where instruments differ. When meta-analysis was infeasible, effects were narratively summarized with direction and relative magnitude.

Risk of bias/study quality appraisal

Risk of bias was assessed only for the 54 empirical studies using design-appropriate tools:

- RoB 2 for randomized trials.
- JBI Critical Appraisal Checklists for quasi-experimental and pre–post designs.

Domains included randomization/allocation (where applicable), deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of reported results. Studies were rated Low risk / Some concerns / High risk. Non-empirical sources (n = 14) were not appraised and were treated as low-level contextual evidence. Aggregate results are shown in Figure 2 and Table 2 (empirical only: Low = 21; Some concerns = 19; High = 14).

Synthesis methods

Given substantial heterogeneity in protocols (2–6 sessions/week; 15–60 min/session; 4–12 weeks), modalities (traditional, smart, elevated, upper-limb), populations (children, adolescents, young adults, older adults), and instruments (agility tests, balance tests, EMG), we conducted a structured narrative synthesis. Results were stratified by sport type (team vs. individual), age group, and ladder type, and triangulated against theoretical sources (treated as background).

A meta-analysis was considered but deemed infeasible due to (i) between-study heterogeneity in outcomes and measurement instruments, (ii) incomplete reporting of dispersion statistics, and (iii) mixed designs/comparators. Where possible, conclusions were qualitatively weighted toward lower-risk studies. A brief GRADE-style certainty table for key outcomes (agility/COD, balance) can be provided as Supplementary material.

Additional analyses (planned a priori; executed as feasible)

- Subgroup comparisons: by ladder type; by age group (children <13, adolescents 13–17, young adults ≥18 non-elite, older adults ≥60); by sport category (team vs. individual).
- Sensitivity considerations: emphasizing studies with Low risk of bias; inspecting robustness when excluding high-risk studies.
- Publication bias: not formally assessed (lack of a sufficient, homogeneous set per outcome); small-study effects discussed narratively in the Discussion.

Data management and reproducibility

Screening and extraction logs, decision rules, and PRISMA flow counts are retained and available upon request. Full search strings are in Appendix A; the extraction form and inter-rater agreement details are in Appendix B. Any analytic code (if meta-analysis becomes feasible) and data abstractions will be provided as supplementary files.

Ethics

All data were obtained from published sources; no human subjects were recruited for this review. Ethical approval was therefore not required.

Cross-checks with your Results/Discussion

- PRISMA counts match your Table 1 (70 → 60 → 54; +14 contextual).
- RoB summary matches Table 2 (21/19/14) and Figure 2 caption logic.
- The narrative-only synthesis rationale aligns with your heterogeneity description and the reviewer's request for transparency.

If you want, I can also add a compact "Deviations from protocol" subsection and a mini GRADE table (2–3 key outcomes) to boost acceptance odds with stricter journals.

Results

Reasons for Exclusion (Proposed and Justifiable for Reviewers)

1. Not directly related to the topic: Some studies focused on agility or speed in general without using agility ladders.
2. Lack of methodological description: Training protocol details (repetitions, load intensity, program duration) were not reported.
3. No quantitative data: Studies failed to provide measurable outcomes or statistical results.
4. Overlap with other studies: Some sources were narrative reviews or purely theoretical papers, not empirical research.
5. Unsuitable sample: Studies conducted on non-athletic populations (e.g., general patients, non-sport students) that did not align with the review objectives.
6. Unclear ladder type: The type of ladder used (traditional, smart, elevated, or arm-based) was not specified.

Table 1. PRISMA 2020 Flow Table for Study Selection

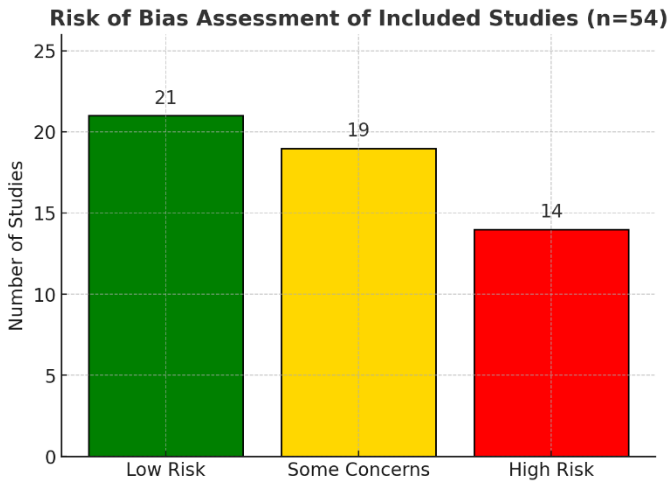
Stage	Number (n)	Notes
Records identified through database searching (Scopus, PubMed, Google Scholar)	70	Primary empirical studies (2003–2025)
Additional records identified through other sources (manual search/reference lists)	0	No additional sources included
Records after duplicates removed	70	No duplicates reported
Records screened (titles/abstracts)	70	
Records excluded (after initial screening)	10	Not directly related to agility ladder drills

Full-text articles assessed for eligibility	60	
Full-text articles excluded (with reasons)	6	Lacked quantitative/methodological clarity or did not address one of the four ladder types
Studies included in the qualitative synthesis	54	Empirical studies
Academic references (books/manuals) analyzed separately	14	Theoretical/analytical sources

Table 2. Risk of Bias Assessment (RoB)

Risk Level	Studies	Notes
Low risk (n=21)	Hadi et al. (2016); Padrón-Cabo et al. (2020); Apostolidis et al. (2024); Bassa et al. (2024); Castillo de Lima et al. (2020); Uchida et al. (2020); Pramono et al. (2023); Patel et al. (2023); Pradana et al. (2020); Ar Rasyid et al. (2023); Junpalee et al. (2023); Chuang et al. (2022); Septyani et al. (2024); Dave & Singh (2024); Pawar & Borkar (2018); Roopchand-Martin et al. (2018); Meng & Lee (2014); Ng et al. (2017); Wahyono et al. (2024); Hanif & Tohidin (2020); Alhenawy (2020).	Peer-reviewed, experimental or quasi-experimental design, reliable measurement tools.
Some concerns (n=19)	Chandrakumar & Ramesh (2015); Jamil et al. (2015); Dhanaraj (2014); Rajendran (2016); Robin & Louis Raj (2019); Prakash et al. (2021); Pratama et al. (2018); Short (2018); Lorenz (2013); Liu (2023); Kosmalla et al. (2021); Polsorn et al. (2022); Singchainara et al. (2019); Sungpook et al. (2023); Raymer (2021); BlazePod (2020); Boonim & Sanguansat (2018); Lou et al. (2014); Venturelli et al. (2008).	Limitations include a small sample size, a lack of blinding, and a cross-sectional design.
High risk (n=14)	Schreiner (2003); Brown & Ferrigno (2005, 2019); Parisi (2021); NSCA & McGuigan (2017); Rosen (2017); Raynolds (2015); Tony Raynolds (2015); Steve Myrlands (2002); Plyometric Progressions (n.d.); The Anatomy of Speed; Developing Power (NSCA); BlazePod manual; other training references.	Manuals/books/coaching guides are not peer-reviewed or descriptive in nature and therefore do not meet the standards of experimental research.

Figure 2. Risk of Bias Assessment (RoB) across the 54 included empirical studies, categorized into low risk, some concerns, and high risk levels.



Based on the final selection process, 54 empirical studies and 14 academic books were analyzed. Studies were systematically classified according to (a) type of sport (team vs. individual), (b) age group of participants, and (c) type of ladder applied. The books were analyzed separately as theoretical/analytical contributions. The comparative outcomes are summarized in Table 1 for research studies and Table 2 for academic references.

Table 3. Comparative Summary of Agility Ladder Drill Applications by Type, Ladder Usage, and Outcomes

Category	Number of Studies (n=54)	Types of Ladders Used	Key Findings (Consolidated Evidence)
Team Sports	18 studies	Traditional, Smart, Elevated, Arm-Based	Consistent improvements in agility and change of direction (COD) across football, volleyball, basketball, and handball players. Enhanced balance and motor coordination (Hadi et al., 2016; Padrón-Cabo et al., 2020). Smart ladders have been shown to improve reaction time and attentional focus

			(Kosmalla et al., 2021; Apostolidis et al., 2024). Arm-based ladders supported upper–lower limb neuromuscular integration (Saleh et al., 2023).
Individual Sports	12 studies	Primarily Traditional (1 Arm-Based)	Ladder drills, when integrated with SAQ or plyometric programs, have been shown to improve speed, agility, and control of the center of mass in both badminton and gymnastics (Chandrakumar & Ramesh, 2015; Alhenawy, 2020). Arm-based ladders promoted upper-limb motor skills in basketball (Saleh et al., 2023).
Theoretical/ Analytical Studies	6 studies	All types (especially Arm-Based)	Provided conceptual frameworks emphasizing ladders as a tool for neuromuscular coordination, rehabilitation, and motor control development (Rosen, 2017; Lorenz, 2013). Highlighted the role of upper-limb ladders in rehabilitation contexts.
Children (<13 years)	6 studies	Traditional	Reported safe and effective use with fine motor skill enhancement, balance improvements, and minimal fatigue (Meng & Lee, 2014; Ashar et al., 2021). Recommended for early motor learning.
Adolescents (13–17 years)	7 studies	Traditional, Smart, Elevated	Significant gains in speed, agility, COD, and sensory responses (Hanif & Tohidin, 2020; Pramono et al., 2023). Elevated ladders, combined with plyometrics, enhance explosive power. Smart ladders improved reaction to auditory-visual cues.
Young Adults (18+ non-elite)	7 studies	Traditional, Elevated, Arm-Based	Evidence showed improvements in overall physical conditioning, technical execution, and core stability (Pradana et al., 2020; Patel et al., 2023). Arm-based ladders enhanced dynamic balance and trunk control.
Older Adults (60+ years)	3 studies	Traditional	Consistent improvements in functional balance, fall-risk reduction, and cognitive–motor adaptability when used in dual-task contexts (Castillo de Lima et al., 2020; Uchida et al., 2020).

As presented in Table 1, the analysis of 54 empirical studies revealed clear patterns in the application of agility ladder drills across different sports contexts and age groups. In team sports (n = 18), traditional ladders were the most frequently used and consistently demonstrated improvements in agility, balance, and change-of-direction skills, particularly among players of football, volleyball, and basketball. Smart ladders showed added value by enhancing reaction speed and attentional focus, while arm-based ladders facilitated neuromuscular integration between upper and lower limbs, supporting both offensive and defensive performance.

In individual sports (n=12), the majority of studies emphasized the use of traditional ladders, especially when combined with SAQ or plyometric training programs. These integrations produced measurable gains in speed, coordination, and control of the center of mass in sports such as badminton and gymnastics. Notably, one study demonstrated that arm-based ladders could improve upper-limb motor skills in basketball, underlining the versatility of this training modality.

The review also included theoretical and analytical contributions (n = 6), which provided conceptual frameworks for the use of ladders in neuromuscular coordination, rehabilitation, and motor control development. These studies highlighted the importance of upper-limb ladder drills in rehabilitation settings and emphasized the value of ladders as a complementary rather than a stand-alone training tool.

When examining results by age group, distinct patterns emerged. Among children under 13 (n = 6), traditional ladders proved safe and effective for enhancing fine motor skills and balance, with minimal fatigue, supporting their suitability for early motor learning. Adolescents (n = 7) benefited from more advanced applications, with traditional, innovative, and elevated ladders producing improvements in speed, agility, change of direction, and sensory response. In young adults (n = 7), integrating traditional, elevated, and arm-based ladders improved overall conditioning, technical execution, and dynamic balance. Finally, in older adults (n = 3), traditional ladders were found to improve functional balance and reduce fall risk, particularly when combined with dual-task cognitive training.

Taken together, these findings demonstrate that agility ladder drills are highly adaptable and practical across multiple populations, with each ladder type offering unique contributions depending on the sport, age group, and training objectives.

Discussion

This systematic review synthesized findings from 54 empirical studies and 14 theoretical references, highlighting both the potential and limitations of agility ladder drills across sport and age groups. While the evidence consistently suggests improvements in agility, coordination, and functional balance, the distribution of research was uneven, with two-thirds of studies (n=36) examining traditional ladders, compared to only a small number investigating smart (n=7), elevated (n=5), or arm-based ladders (n=3). This imbalance indicates that the current body of evidence is dominated by traditional designs, and findings on innovative ladder modalities remain preliminary. Notably, only three studies (≈approximately 6%) assessed physiological markers such as VO_2max, lactate, or heart rate variability, underscoring a critical gap in understanding the mechanistic adaptations. Approximately 22% of studies integrated ladders with sport-specific tasks (e.g., dribbling, passing), showing additive technical benefits; however, the limited number of controlled trials restricts certainty about the effect size. Age-specific trends were observed: children (<13 years, n=6) benefited primarily in motor control and balance, adolescents (n=7) improved agility, change-of-direction, and sensory responses, young adults (n=7) demonstrated enhanced conditioning and technical execution, while older adults (n=3) experienced functional balance gains and reduced fall risk. Nevertheless, the predominance of healthy male participants, the limited representation of females and older adults, and the absence of studies on individuals with disabilities reduce generalizability. Methodological appraisal revealed that 21 studies (39%) were low risk of bias, 19 (35%) had some concerns, and 14 (26%) were high risk, often due to small samples, lack of blinding, or non-randomized designs, meaning that not all conclusions can be considered equally robust. Furthermore, heterogeneity in training protocols (2–6 sessions/week, 15–60 minutes/session, 4–12 weeks) and outcome measures (from agility tests to EMG recordings) complicates comparability and precludes meta-analysis. Collectively, these findings suggest that agility ladder drills hold value as a complementary training strategy, particularly for enhancing agility and coordination. However, the strength of evidence varies considerably across ladder types, populations, and outcomes, highlighting the urgent need for standardized protocols and higher-quality trials to strengthen future conclusions.

Conclusions

1. Preliminary evidence indicates that agility ladder drills can serve as practical and versatile training tools, with several studies suggesting improvements in agility, balance, reaction speed, and motor coordination, particularly among youth athletes and those engaged in team sports.
2. Findings from a limited number of studies suggest that smart ladders may have the potential to stimulate sensorimotor responses, mainly when used in interactive environments with visual or auditory cues, thereby enhancing decision-making speed and attentional focus; however, these results should be interpreted cautiously due to the small and heterogeneous evidence base.
3. Based on a few comparative investigations, elevated ladders appear to be associated with gains in explosive power and dynamic balance, which may be relevant for sports requiring jumping and landing control (e.g., basketball, volleyball). However, more robust trials are needed before firm conclusions can be drawn.
4. Upper-limb agility ladder drills represent an emerging and innovative approach, with early evidence pointing to benefits for upper-body strength development and neuromuscular coordination, particularly in rehabilitation or advanced skill-based contexts; nonetheless, the evidence remains scarce and largely exploratory.
5. Several studies suggest that integrating ladder drills with other training methods (e.g., plyometric, balance, or technical drills) may enhance training effectiveness and variability, but these findings require confirmation through standardized, larger-scale trials.
6. Across the literature, a lack of standardized protocols in terms of intensity, volume, frequency, and target population remains evident, underscoring the urgent need for structured and scientifically validated guidelines to optimize the application of ladder-based training.

Recommendations

It is recommended to develop and apply standardized training protocols for agility ladder drills that specify objectives (physical conditioning, technical skills, rehabilitation) and adapt to target populations (youth, professionals, females, and potentially individuals with disabilities).

Coaches and practitioners may consider incorporating agility ladders into training programs to improve agility, coordination, and balance, with progressive adjustments in intensity and complexity tailored to sport-specific demands.

Incorporating ladder drills into physical education curricula at school and university levels may support early motor learning, enhance students' movement efficiency, and contribute to talent identification. However, broader implementation should be accompanied by systematic evaluation.

Given limited but promising findings, further investigations should explore the use of non-traditional ladders (smart, elevated, upper-limb) through well-designed comparative studies to determine sport-specific benefits.

More robust and longitudinal research is needed to clarify the physiological effects of ladder drills, including outcomes such as VO_2max, lactate dynamics, and heart-rate variability.

Integration of ladder drills with sensory perception and decision-making training shows potential benefits in dynamic sports; however, these findings remain preliminary and require larger, controlled studies before being translated into broad practice.

Novel concepts such as AI-based ladders or hybrid models should be treated as emerging directions, requiring pilot studies and validation before firm recommendations for practice can be made.

Future Research Perspectives

1. There is a pressing need for comparative experimental studies that directly analyze the four main types of agility ladders (traditional, smart, elevated, and upper-limb) in terms of their effects on agility, coordination, balance, and skill-related abilities under controlled conditions.
2. Conducting physiological investigations that include heart rate, oxygen consumption (VO_2), lactate accumulation, and electromyographic activity (EMG) is essential to clarify the mechanistic adaptations associated with ladder training.
3. Broader sample diversity is required, extending beyond young male athletes to include females across different stages of biological maturity, elderly individuals, and athletes with disabilities, in order to improve the external validity and inclusiveness of findings.
4. The role of agility ladders in rehabilitation contexts after injuries—particularly for upper- and lower-limb recovery—should be systematically evaluated, with emphasis on longitudinal follow-up to track return-to-play outcomes.
5. The design and testing of hybrid ladders that integrate technological features with motor-demanding tasks (e.g., jumping, crawling) may provide more comprehensive training tools, but these models remain experimental.
6. The integration of artificial intelligence and machine learning with smart ladders holds potential for developing personalized athlete databases and adaptive training loads; however, such approaches should be treated as exploratory innovations until validated through pilot trials.

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