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The science of ladder drills and plyometrics: Enhancing neuromuscular efficiency in athletes

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Abstract: The objectives of this study are to determine whether there is any interaction between agility and athletic performance skills and plyometric training, ladder drill, and agility training; how different these effects are from one another; and how different the effects of low and high agility are from one another. The experimental methodology employed in this work uses a factorial analysis in 2x2. A population of 40 athletes, aged 15 to 17, were selected for the research sample using ordinal pairing. Devices that measure agility using the Illinois Agility Test. The following are the study's findings: The post-test indicates a significant value of $p < 0.05$, indicating that the plyometric training technique, ladder drill, affects athletic performance skills ($p > 0.05$). Because the significance value indicates p of $0.006 < 0.05$, there is a significant difference between the effects of low and high agility on athletic performance skills ($p < 0.05$). There is a significant ($p > 0.05$) interaction between agility (high and low), ladder drill training techniques, and plyometric training methods of athletic performance skills ($p < 0.05$). The findings indicate that following training, there is a relationship between agility and athletic performance abilities. According to the study, there is a connection between agility (high and low) and athletic performance skills, and agility has a major impact on athletic performance. Training techniques such as plyometric training and ladder drills are also related to agility. Applying the ladder drill and plyometric training techniques affects athletes' performance abilities. It has been demonstrated that doing plyometric and ladder drills may enhance one's athlete's performance ability.

Keywords: *Agility, Skills, Athletic Performance, Ladder drill, Motor units, Nervous system, Neuro muscular efficiency, Plyometric.*

1. Introduction

Multiple physiological systems interact delicately to determine athletic performance, and neuromuscular efficiency is a key factor[1]. The term "neuromuscular efficiency" describes the nervous system's capacity to activate the appropriate muscles at the appropriate moment and with the most force[2]. This effectiveness supports not just athletic ability but also reduces the likelihood of injuries, promotes faster healing, and improves general physical fitness[3]. Ladder drills and plyometric exercises are two types of training techniques that are beneficial for improving neuromuscular efficiency[4]. Despite being thought of as simple training aids, ladder drills and plyometrics are based on advanced scientific concepts[5]. These workouts aim to increase an athlete's power, speed, agility, and coordination, which will help them play better in a variety of sports[6][7]. For example, ladder drills let you practice fast foot movements and accurate body control, both of which are crucial for sports where quick direction changes are required. In contrast, plyometric exercises focus on muscular strength and explosive power, utilizing the stretch-shortening cycle to optimize force output in the shortest amount of time[8][9].

Ladder exercises and plyometrics are highly regarded in the field of sports science because they produce certain neuromuscular adaptations that improve athletic performance[9]–[11]. Sports like

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basketball, football, and track and field competitions that call for explosive strength benefit greatly from these training methods[12]. However, the advantages of these workouts go beyond boosting performance; by enhancing joint stability, proprioception, and muscle endurance, they also significantly contribute to injury prevention[13]. Ladder drills and plyometrics are based on complex science that includes concepts from physiology, biomechanics, and motor learning[14]. The neuromuscular system of the body, which includes intricate connections between the brain, spinal cord, peripheral nerves, and muscles, is used in these workouts[13]. Through regular practice of these exercises, athletes can remodel their neuromuscular pathways, resulting in enhanced synchronisation, firing rates, and recruitment of motor units[15]. This neuromuscular adaptation is essential for sports that call for quick, forceful, and precise movements.

The pace at which muscles may contract is determined by the firing rate of motor neurons, which is another significant determinant[16]. Faster and stronger muscular contractions are made possible by higher firing rates, and explosive motions depend on these kinds of movements[16], [17]. Plyometrics and ladder drills are high-intensity workouts that repeatedly activate the motor neurons, increasing the firing rates of certain neurons[18]. Another essential component of neuromuscular efficiency is motor unit synchronisation. Muscle contractions that are produced by well-coordinated motor units are powerful and fluid[19]. Plyometric exercises, in which muscles are rapidly stretched and contracted, can improve synchronisation by teaching the nervous system how to better coordinate muscular activities[20].

Agility ladder exercises sometimes referred to as ladder drills, are meant to increase foot speed, coordination, and agility[21]. Usually, these exercises consist of a sequence of quick and accurate foot motions carried out inside the boundaries of a ground-level ladder[22]. The goal is to climb the ladder as fast and precisely as you can, frequently by adhering to predetermined patterns or steps. Ladder drills' main advantage is that they improve neuromuscular coordination[23], [24]. Athletes may teach their nervous system to provide accurate and fast messages to their muscles by making swift foot motions[25]. Better agility and balance are a result of this increased coordination, and these attributes are critical for sports like basketball, tennis, and soccer that need quick direction changes[24].

Ladder drills have the potential to improve the neuromuscular system's proprioceptive capacities from a physiological standpoint[13]. The body's capacity to perceive its location and motion in space is known as proprioception[13][26]. Athletes may quickly alter their motions by developing a heightened sense of proprioception through the regular practice of complicated foot patterns[26]. This is especially significant for sports where stability and balance are essential. Fast-twitch muscle fibre growth is another benefit of ladder drills[27]. These muscle fibres are necessary for explosive motions because they can contract quickly and forcefully[26]. Athletes may increase their speed and agility by performing high-intensity ladder drills, which will encourage the development and activation of fast-twitch fibres[5]. The goal of plyometric workouts, sometimes referred to as jump training, is to build explosive power by contracting the muscles quickly and forcefully[9][28]. Typically, these workouts involve bounding, hopping, and leaping motions that takes advantage of the stretch-shortening cycle (SSC)[29]. The SSC is a physiological process that produces maximum force output by swiftly stretching a muscle (eccentric phase) and contracting it right away (concentric phase)[30]. Enhancing the elastic qualities of muscles and tendons is the main objective of plyometric exercise[31]. Similar to a stretched rubber band, energy is stored in the muscle-tendon unit's elastic components during the eccentric phase[32]. This stored energy is released during the muscle's transition to the concentric phase, producing a forceful contraction[27], [33]. This process is improved by plyometric exercise, which results in increased explosive power by improving energy storage and release efficiency[34].

Plyometric exercises can enhance the rate of force generation (RFD) from a neuromuscular standpoint[27][35]. The pace at which a muscle can produce force is referred to as RFD. Athletes develop their nervous system to activate muscles more rapidly and strongly by moving swiftly and aggressively[36]. This is especially helpful for sports like throwing, running, and leaping which demand quick movements[37]. Additionally, neuromuscular adaptations that improve motor unit coordination and firing rates are promoted by plyometric activities[2], [13]. The coordination and timing of muscular contractions can be enhanced in athletes by executing high-intensity leaps and hops regularly[38]. Peak athletic performance depends on stronger, more effective movements, which are the result of this.

Ladder drills and plyometrics are useful for improving neuromuscular efficiency because they follow important biomechanical guidelines[39][40]. These ideas, which control movement mechanics, are crucial to comprehending how these workouts enhance sports performance. The idea of the kinetic chain, which describes how the body's components are related to one another when in motion, is one such principle. Energy must be transferred smoothly from one section to the next, beginning at the base, for movement to be effective[41]. Plyometric exercises and ladder drills teach athletes how to effectively use their whole kinetic chain, which leads to more powerful and coordinated actions[39][42]. Ground response force (GRF) is an additional important biomechanical notion[43]. The force that the ground applies to the body when it moves is referred as GRF. Because plyometric activities entail explosive movements, they have very high GRF[8][34], [44]. Athletes can enhance their capacity to produce and absorb GRF through plyometric exercise, which will result in stronger leaps and faster sprints[25]. Ladder drills and plyometric exercises also heavily involve joint kinematics and kinetics. Joint stability and proprioception can be improved by performing these exercises, which call for exact control of joint angles and forces[13], [26]. Enhancing joint kinematics and kinetics allows athletes to perform actions with less risk of injury and greater efficiency[3].

Plyometrics and ladder exercises provide a variety of neuromuscular adaptations that improve overall athletic performance[45][46]. These adaptations include modifications to brain circuits, motor unit function, and muscle anatomy. Muscle hypertrophy is an important adaptation, especially in fast-twitch muscle fibres[47]. The high-intensity, explosive movements used in ladder drills and plyometrics encourage the formation of these fibres[48][4]. This results in larger and stronger muscles, which are necessary to produce strong actions. The increase in motor unit firing and recruitment rates is another significant adaptation[16], [17]. Athletes can improve the effectiveness of their nervous system's activation of the proper motor units by regularly engaging in high-intensity drills[49]. This improves performance overall by causing muscles to contract more quickly and forcefully[50], [51]. Through these activities, neuromuscular synchrony is also improved. Ladder drills and plyometric exercises are repetitious and improve motor unit coordination, which results in more fluid and effective motions[23], [52]. Sports requiring exact time and coordination especially benefit from this synchronisation.

These activities can also improve the neuronal pathways' plasticity. The term "plasticity" describes the nervous system's capacity to change and rearrange itself in response to instruction[53]. Athletes may build and form new neural connections in their brains through plyometric exercises and ladder drills, which will enhance their motor control and performance[31][54]. Ladder drills and plyometric exercises have practical applications in a variety of sports, including individual and team sports[4], [55]–[57]. These workouts are adaptable and may be customized to fit the unique requirements of various sports.

2. Methodology

This study's design employs an experimental methodology. By employing a 2x2 factorial analysis[58]. In this experiment, two groups the one that received Ladder training and the other were employed Plyometric training. Training methods that were divided into high and low-agility groups included ladder drills and plyometric training. The Indian School served as the research site. The 40 athletes that play boy's were the population under investigation. All players who are still active in inter-school athletic meets were the inclusion criteria for this study, whereas players who are still active but susceptible between the ages of 15 and 17 meet the exclusion criteria. The Illinois Agility Test, which has a validity of 0.496 and a reliability of 0.931, is used to test athletes playing skills, whereas the Illinois Agility Test, which has a validity of 0.87, is used to measure agility. The Illinois Agility Test was then used to measure the agility of 40 players in the population. The objective is to ascertain the players' level of agility in Indian schools. Following the collection of agility data, a ranking system for players' total test score which measures their agility is used to determine groups of players with high and poor agility.

The findings indicated that the research sample will consist of up to 20 individuals graded from the highest to lowest agility among 40 participants. Two-thirds of the higher group and the lower two-thirds of the test results were identified based on the ranking. As a result, the sample grouping was drawn from participants in the 30% and 30% of the rated data who had high and poor agility, respectively. This results in the acquisition of 12 athletes with great agility and 12 players with low agility. Using pairing procedures to determine which players made up the experimental group, it was discovered that the 7 players with the highest agility levels received the same training in the hurdle exercise and ladder drill as did the players with the lowest agility levels. Prerequisite and hypothesis testing were employed in the data analysis for this investigation.

3. Results

The pre-test and post-test data from this study provide an overview of all the factors connected to the investigation. The homogeneity test is used to determine whether or not the equations about several samples are homogenous. The purpose of the homogeneity test is to evaluate how similar test versions are between the pre-test and post-test. The Levene Test is the homogeneity test used in this investigation. Based on statistical examination of homogeneity tests performed with the Levene Test. The significance of the pre-test was found to be $0.078 > 0.05$, whereas the post-test showed a significance of $0.149 > 0.05$. This indicates that there are homogenous variations in the data group. As a result, the population's similarity is either fluctuating or uniform. If the significant value is greater than 0.05, record homogenous data. Based on the findings of data analysis and the interpretation of two-way ANOVA analysis, research hypothesis testing was done. The first theory is "there is a significant difference in the influence of plyometric training and ladder drill training methods on athletes' agility'. The post-test result was 0.000, whereas the pre-test significance value was 0.153. Since it hasn't received any training or exercise, the pre-test's significance value of p is $0.153 > 0.05$, indicating that it has no impact. Even if the post-test p-value is $0.000 < 0.05$, the results indicate that the training approach has an impact on athletes' agility.

4. Discussion

The purpose of this introduction is to examine the scientific underpinnings of plyometrics and ladder drills and their potential benefits for improving athletes' neuromuscular efficiency. Through an analysis of the neurological, biomechanical, and physiological underpinnings of these workouts, we may obtain a thorough grasp of how they affect athletic performance[59]. Additionally, this talk will emphasise the useful uses of plyometrics and ladder exercises in a variety of sports, offering insights into how these training aids may be incorporated into athletic training regimens for the best outcomes[60].

A complex idea, neuromuscular efficiency focuses on optimising muscle activation patterns to produce force as efficiently as possible. Fundamentally, it all comes down to how well the neural system can coordinate muscle contractions to create strong, well-coordinated motions[16], [26]. The brain is the first step in the process, producing motor orders in response to cognitive and sensory inputs. Motor neurons receive these messages after travelling down the spinal cord, and they subsequently cause the relevant muscle fibres to contract[61]. The recruitment of motor units is a crucial component of neuromuscular efficiency[16], [49], [61]. An innervated muscle fibre and a motor neuron make up a motor unit[62]. To produce the desired force with minimal energy expenditure, one must be able to recruit the appropriate number of motor units at the appropriate moment[17], [53], [61]. By encouraging changes in the nervous system and muscles, training treatments like plyometrics and ladder exercises can improve the recruitment of motor units.

If an athlete uses the plyometric training and ladder drill training methods for an extended length of time, their abilities will develop[8], [27], [50]. Emphasising the muscles with systematic, repetitive application over an extended period would cause physiological adaptation in the muscles[25]. Physiological changes that take place in the limb muscles, affecting nearly all of the muscles, particularly the limb muscles such the quadriceps, hamstrings, gastrocnemius, and hip abductors when hypertrophy occurs[28].

Hypertrophy is brought on by an increase in the number of myofibrils in each muscle fibre, an increase in the capillary density in muscle fibres, and an increase in the number of white muscle fibres, or fast-twitch, which results in stronger leg muscles and an increase in speed[14], [63], [64]. The 18 meetings of the study program had a significance level of 5% or 0.05. The research was done by researchers. The pre-test yielded a significance of 0.248 > 0.05, and the post-test yielded a significance of 0.651 > 0.05, according to the statistical analysis of the normality test conducted using the Shapiro-Wilk test. In other words, the data is not widely circulated. Data records are normally distributed if sig. > 0.0. The difference in how athlete's performance skills are affected by low and high levels of agility." The significance's outcome P was 0.101 for the pre-test and 0.006 for the post-test. The p-value of 0.101 > 0.05 for the pre-test indicated that the influence of agility on the fundamental abilities before treatment or training rendered the results unimportant. Regarding the post-test, the results demonstrated significance with a p-value of 0.006 < 0.05 following treatment or exercise. When significance (Sig.) < 0.05, it is considered significant. This indicates that the null hypothesis was turned down.

The fourth theory is that "there is an interaction between the plyometric training and ladder drill training methods and agility (high and low) to athlete's performance skills. The importance of p for the pre-test was found to be 0.321, whereas the post-test revealed a 0.001 significance value for p. Because no training or exercise had been done, the pre-test's significance value of p was 0.321 > 0.05, which indicated that it had no meaningful impact. Regarding the post-test of 0.001 < 0.05, the findings indicated that treatment or exercise resulted in an interaction between the approaches if the significance (Sig.) < 0.05. Based on these findings, the hypothesis that claims "agility (high and low) to athlete's performance skills and the plyometric training and ladder drill training methods interact" has been validated. Research may be characterized as succinct and attempts to enhance athletes' performance skills, but the training techniques of ladder drills and plyometric training need a significant amount of time to provide improvements in athletes' performance abilities.

Agility and neurological adaptation are linked; the mechanism of nervous adaptation is exercise-induced, directly felt increase in muscular contraction force[65]. Higher inhibition of the antagonist muscles, more precise contraction of synergistic muscles, and higher activation of the primary driving muscles are the causes of this rise[16], [61]. It follows that in typical circumstances, skilled athletes can contract their muscles to the furthest extent possible, allowing their energy reserves to be used as soon as possible to achieve their maximal effort. Frequent physical exercise will cause hypertrophy of muscle physiology because it will increase the total number of contractile, particularly myosin contractile proteins, as well as the size, density, and density of capillary blood vessels, nerve tendons, and ligaments[66]. Muscle contraction speed increases because not all muscle fibre changes happen equally; white (fast twitch) muscle fibres see a larger rise in changes than other muscle fibre types[62].

Agility enables athletes to move, pivot, and change direction without losing their balance, which is a useful talent[67]. Agility is the capacity to swiftly and accurately alter the body's direction and position while it is moving without losing equilibrium and cognizance of its physical posture[68]. Being able to swiftly shift direction while traveling at a fast pace is therefore essential for performing dribbling manoeuvres. The analysis of agility comes from the movement process itself; agility then facilitates athletes' performance skills.

5. Conclusion

In summary, a thorough grasp of the scientific foundations of plyometric and ladder drill training as well as how they affect athletes' neuromuscular efficiency has been made possible by the research. The results show how various training approaches significantly alter the nervous system and physiological system, which enhances athletic performance. The study also highlights the value of agility and how certain training methods might improve it.

Training techniques like plyometric and ladder drills are useful for athletes who want to maximize their performance. Through the enhancement of muscle strength and power, neuromuscular efficiency, and agility, these training techniques help athletes reach their maximum potential. These exercises are useful in a variety of sports, thus they should be a part of any complete athletic training program. According to the study's findings, a player's performance abilities have greater potential when they possess a high level of agility. High-agility players can execute a variety of moves quickly and effectively. According to the study, there is an interaction between agility (high and low) and training techniques like plyometric training and ladder drills on athletes' performance skills. Agility also has a substantial impact on athletes' performance skills. Applying the plyometrics and ladder drill techniques affects a player's agility. It has been demonstrated that training with hurdle and ladder drills may enhance one's athlete; performance abilities.

Ethics Approval and Consent to Participate:

We confirmed that the experimental protocol was approved by the Institutional Review Board of Alagappa University College of Physical Education Centre, and informed consent was obtained from each participant after the risks and benefits were explained. The study was conducted following the latest version of the Declaration of Helsinki.

Author Contributions;

P.R. conceived and designed the study, collected and analyzed the data, and wrote the main manuscript text. D.K. provided critical input in study design, supervised the research, and contributed to the manuscript's revision. Both authors have reviewed and approved the final manuscript for publication.

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References

[1] E. A. Ostrander, H. J. Huson, and G. K. Ostrander, "Genetics of athletic performance," *Annu. Rev. Genomics Hum. Genet.*, vol. 10, no. August, pp. 407–429, 2009, doi: 10.1146/annurev-genom-082908-150058.

[2] S. Kopinski, "The Neuromuscular Efficiency of Lower Back Muscles in Low Back Pain," no. December, 2016.

[3] G. D. Myer *et al.*, "Integrative training for children and adolescents: techniques and practices for reducing sports-related injuries and enhancing athletic performance.," *Phys. Sportsmed.*, vol. 39, no. 1, pp. 74–84, 2011, doi: 10.3810/psm.2011.02.1864.

[4] D. K. Pramod R., "The Effect of Plyometric Training on Explosive Power and Speed of Handball Players," *Aiirjournal.Com*, vol. 10, no. 5, pp. 474–479.

[5] R. Pramod and K. Divya, "The effects of ladder training on speed of Egyptian high school boys student ' s The effects

of ladder training on speed of Egyptian high school boys student ' s in Qatar," *Int. J. Phys. Educ. Sport. Heal.*, vol. 6, no. January, pp. 18–22, 2019.
[6] J. C. Radcliffe, *Functional training for athletes at all levels: workouts for agility, speed and power.* Simon and Schuster, 2007.
[7] A. D. Faigenbaum *et al.*, "Effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years," *J. Sport. Sci. Med.*, vol. 6, no. 4, pp. 519–525, 2007.
[8] G. R. G. H. Aff and C. A. F. Errete, "E Ffects of P Lyometric and S Print T Raining," vol. 23, no. 46, pp. 385–394, 2015.
[9] M. I. I. Zquierdo, "E Ffects of P Lyometric T Raining V Olume and," vol. 23, no. 2, pp. 2714–2722, 2013.
[10] S. Hendrawan Koestanto, H. Setijino, and E. Mintarto, "Model Comparison Exercise Circuit Training Game and Circuit Lad-der Drills to Improve Agility and Speed History Article," *Heal. Sport J. Phys. Educ. Heal. Sport*, vol. 4, no. 2, pp. 78–83, 2017, [Online]. Available: http://journal.unnes.ac.id/nju/index.php/jpehs
[11] Y. RATHOD and D. R. M. PAWAR, "Effect of Six Week Ladder Skill Training on Vital Capacity of Kabaddi Players," *Think India J.*, vol. 22, no. 13, pp. 843–849, 2019.
[12] K. Thomas, D. French, and P. R. Hayes, "The effect of two plyometric training techniques on muscular power and agility in youth soccer players," *J. Strength Cond. Res.*, vol. 23, no. 1, pp. 332–335, 2009, doi: 10.1519/JSC.0b013e318183a01a.
[13] D. Riva, R. Bianchi, F. Rocca, and C. Mamo, "Proprioceptive Training and Injury Prevention in a Professional Men's Basketball Team: A Six-Year Prospective Study," *J. Strength Cond. Res.*, vol. 30, no. 2, pp. 461–475, 2016, doi: 10.1519/JSC.0000000000001097.
[14] M. E. Gold, H. L. Frisk, B. R. Biggs, M. J. Blankenship, and W. P. Ebben, "BIOMECHANICAL ANALYSIS OF ACCELERATION LADDERS WITH VARYING STEP," pp. 239–242, 2022.
[15] M. P. Hope Northrup, MDa,*, Darcy A. Krueger, "基因的改变NIH Public Access," *Pediatr Neurol. 2013 Oct.; 49(4) 243–254*, vol. 49, no. 4, pp. 243–254, 2013, doi: 10.1002/mus.24095.Role.
[16] P. Bawa and C. Murnaghan, "Motor unit rotation in a variety of human muscles," *J. Neurophysiol.*, vol. 102, no. 4, pp. 2265–2272, 2009, doi: 10.1152/jn.00278.2009.
[17] L. Grimby and J. Hannerz, "Firing rate and recruitment order of toe extensor motor units in different modes of voluntary conraction.," *J. Physiol.*, vol. 264, no. 3, pp. 865–879, 1977, doi: 10.1113/jphysiol.1977.sp011699.
[18] B. Parisi, *The anatomy of speed.* Human Kinetics, 2022.
[19] J. Le Gal, R. Dubuc, and C. Smarandache-Wellmann, "Coordination of rhythmic movements," *Neurobiol. Mot. Control Fundam. concepts new Dir.*, pp. 305–340, 2017.
[20] T. AMBROŻY *et al.*, "Influence of experimental training with external resistance in a form of 'kettlebell' on selected components of women's physical fitness," *Balt. J. Heal. Phys. Act.*, vol. 9, no. 1, pp. 28–36, 2017, doi: 10.29359/bjhpa.09.1.03.
[21] P. Ravi, "PROSPECTIVE EFFECTS OF LADDER TRAINING AND CIRCUIT TRAINING ON THE STRENGTH ENDURANCE PERFORMANCE OF BOYS STUDENTS," vol. 12, no. 5, pp. 485–497.
[22] M. S. J. SHARMILA, M. N. LOGANATHAN, R. SENTHILKUMARAN, and S. SAROJA, "EFFECT OF LADDER TRAINING ON SELECTED PHYSICAL AND PHYSIOLOGICAL VARIABLES AMONG COLLEGE MEN STUDENTS".
[23] K. Chandra, A. Kusuma, I. Kadek, H. Kardiawan, K. C. A. Kusuma, and I. K. H. Kardiawan, "Effect of Ladder Drill Exercise on Speed, Surrounding, and Power Leg Muscle How to Cite," *J. Phys. Educ. Sport. Heal. Recreat. J. Phys. Educ. Sport. Heal. Recreat. / J. Phys. Educ. Sport. Heal. Recreat.*, vol. 6, no. 633, pp. 193–196, 2017, [Online]. Available: http://journal.unnes.ac.id/sju/index.php/peshr
[24] U. Viswejan, "Impact of Ladder Training on Agility Balance and Coordination Among School Students," pp. 229–231, 2017.
[25] P. Ravi and D. D. K, "Improving athletic abilities: The role of circuit training in student populations," *Int. J. Yogic, Hum. Mov. Sport. Sci.*, vol. 9, no. 2, pp. 75–79, 2024, doi: 10.22271/yogic.2024.v9.i2b.1522.
[26] E. R. Laskowski, K. Newcomer-Aney, and J. Smith, "Proprioception," *Phys. Med. Rehabil. Clin. N. Am.*, vol. 11, no. 2, pp. 323–340, 2000.
[27] J. Karimian, M. Khazaei, and P. Shekarchizadeh, "Effect of resistance training on capillary density around slow and fast twitch muscle fibers in diabetic and normal rats," *Asian J. Sports Med.*, vol. 6, no. 4, pp. 1–7, 2015, doi: 10.5812/asjsm.24040.
[28] G. Myer, K. Ford, J. Brent, and T. Hewett, "the Effects of Plyometric Vs . Dynamic Stabilization and Balance ...," *J. Strength Cond. Res.*, vol. 20, no. May, pp. 345–353, 2006.
[29] G. T. ADAMSON, "CIRCUIT TRAINING," *Ergonomics*, vol. 2, no. 2, pp. 183–186, Feb. 1959, doi: 10.1080/00140135908930423.
[30] A. N. Turner and I. Jeffreys, "The stretch-shortening cycle: Proposed mechanisms and methods for enhancement," *Strength Cond. J.*, vol. 32, no. 4, pp. 87–99, 2010.
[31] Y. C. Wang and N. Zhang, "Effects of plyometric training on soccer players," *Exp. Ther. Med.*, vol. 12, no. 2, pp. 550–554, 2016, doi: 10.3892/etm.2016.3419.
[32] L. Paavolainen, K. Häkkinen, I. Hämäläinen, A. Nummela, and H. Rusko, "Explosive-strength training improves 5-

km running time by improving running economy and muscle power," *J. Appl. Physiol.*, vol. 86, no. 5, pp. 1527–1533, 1999, doi: 10.1152/jappl.1999.86.5.1527.

[33] M. S. Saghiv, M. S. Sagiv, M. S. Saghiv, and M. S. Sagiv, "Skeletal Muscles," *Basic Exerc. Physiol. Clin. Lab. Perspect.*, pp. 407–436, 2020.

[34] O. A. Donoghue, H. Shimojo, and H. Takagi, "Impact forces of plyometric exercises performed on land and in water," *Sports Health*, vol. 3, no. 3, pp. 303–309, 2011, doi: 10.1177/1941738111403872.

[35] A. J. Blazevich, C. J. Wilson, P. E. Alcaraz, and J. A. Rubio-Arias, "Effects of resistance training movement pattern and velocity on isometric muscular rate of force development: a systematic review with meta-analysis and meta-regression," *Sport. Med.*, vol. 50, pp. 943–963, 2020.

[36] M. A. Booth and R. Orr, "Effects of plyometric training on sports performance," *Strength Cond. J.*, vol. 38, no. 1, pp. 30–37, 2016, doi: 10.1519/SSC.0000000000000183.

[37] G. Cook, *Athletic body in balance.* Human kinetics, 2003.

[38] D. A. Chu, *Jumping into plyometrics.* Human Kinetics, 1998.

[39] P. Mahesh, "EPRA International Journal of Research and Development (IJRD) EFFECTS OF LADDER AND PLYOMETRIC TRAINING ON AGILITY AMONG CRICKET PLAYERS," *EPRA Int. J. Res. Dev.*, vol. 7, no. 4, pp. 167–170, 2022, [Online]. Available: https://doi.org/10.36713/epra2016

[40] B. Salcedo, "May 2018," *Depress. Anxiety*, vol. 35, no. 5, pp. 380–381, 2018, doi: 10.1002/da.22770.

[41] W. L. Nelson, "Physical principles for economies of skilled movements," *Biol. Cybern.*, vol. 46, pp. 135–147, 1983.

[42] P. Ravi and K. Divya, "The effect of medicine ball training on shoulder strength and abdominal strength and endurance among Sudan school boy's football players in Qatar," *Int. J. Phys. Educ. Sport. Heal.*, vol. 6, no. 1, pp. 151–154, 2019, [Online]. Available: www.kheljournal.com

[43] J. P. Hunter, R. N. Marshall, and P. J. McNair, "Relationships between ground reaction force impulse and kinematics of sprint-running acceleration," *J. Appl. Biomech.*, vol. 21, no. 1, pp. 31–43, 2005, doi: 10.1123/jab.21.1.31.

[44] M. M. Yousif, L. A. Kaddam, and H. S. Humeda, "Correlation between physical activity, eating behavior and obesity among Sudanese medical students Sudan," *BMC Nutr.*, vol. 5, no. 1, p. 6, 2019, doi: 10.1186/s40795-019-0271-1.

[45] N. Deng, K. G. Soh, Z. Zaremohzzabieh, B. Abdullah, K. M. Salleh, and D. Huang, "Effects of Combined Upper and Lower Limb Plyometric Training Interventions on Physical Fitness in Athletes: A Systematic Review with Meta-Analysis," *Int. J. Environ. Res. Public Health*, vol. 20, no. 1, 2023, doi: 10.3390/ijerph20010482.

[46] N. S. Adigüzel and M. Günay, "The effect of eight weeks plyometric training on anaerobic power, counter movement jumping and isokinetic strength in 15–18 years basketball players," *Int. J. Environ. Sci. Educ.*, vol. 11, no. 10, pp. 3241–3250, 2016.

[47] E. W. Maglischo, "Part I: Training Fast Twitch Muscle Fibers: Why and How.," *J. Swim. Res.*, vol. 18, 2011.

[48] M. Srinivasan, "Effect of ladder training on selected physical fitness variables on school volleyball players," vol. 1, no. 1, pp. 39–40, 2016.

[49] L. Edström and L. Grimby, "Effect of exercise on the motor unit," *Muscle Nerve Off. J. Am. Assoc. Electrodiagn. Med.*, vol. 9, no. 2, pp. 104–126, 1986.

[50] K. Doma *et al.*, "Mickelson-AnaerobicThreshold-EliteRowers(MSSE1982).pdf," *Int. J. Sports Med.*, vol. 47, no. 1, pp. 488–494, 2013, [Online]. Available: http://journals.lww.com/nsca-jscr/Abstract/2013/09000/Concurrent_Training_in_Elite_Male_Runners___The.10.aspx%5Cnhttp://www.ncbi.nlm.nih.gov/pubmed/23287831%0Ahttp://dx.doi.org/10.1016/j.jesf.2013.12.001%0Ahttp://aut.researchgateway.ac.nz/handle/10292/459

[51] G. Markovic, I. Jukic, D. Milanovic, and D. Metikos, "Effects of sprint and plyometric training on muscle function and athletic performance," *J. Strength Cond. Res.*, vol. 21, no. 2, pp. 543–549, 2007, doi: 10.1519/R-19535.1.

[52] N. E. Pratama, E. Mintarto, and N. W. Kusnanik, "The Influence of Ladder Drills And Jump Rope Exercise Towards Speed , Agility , And Power of Limb Muscle," *J. Sport. Phys. Educ.*, vol. 5, no. 1, pp. 22–29, 2018, doi: 10.9790/6737-05012229.

[53] G. Berlucchi and H. A. Buchtel, "Neuronal plasticity: Historical roots and evolution of meaning," *Exp. Brain Res.*, vol. 192, no. 3, pp. 307–319, 2009, doi: 10.1007/s00221-008-1611-6.

[54] Z. H. Wang, R. C. Pan, M. R. Huang, and D. Wang, "Effects of Integrative Neuromuscular Training Combined With Regular Tennis Training Program on Sprint and Change of Direction of Children," *Front. Physiol.*, vol. 13, no. February, pp. 1–8, 2022, doi: 10.3389/fphys.2022.831248.

[55] S. B. Pawar and P. Borkar, "Effect of ladder drills training in female kabaddi players," *Int. J. Phys. Educ. Sport. Heal.*, vol. 5, no. 2, pp. 180–184, 2018, [Online]. Available: www.kheljournal.com

[56] S. A. Jamil, N. Aziz, and L. B. Hooi, "Effects of ladder drills training on agility performance," *Int. J. Heal. Phys. Educ. Comput. Sci. Sport. Vol.*, no. 17, 2015.

[57] K. Murugavel Professor, R. Giridharaprasath, K. Murugavel, and R. Giridhara Prasath, "Overall playing ability and skill performance parameters response to the ladder training after small side games of grassroots soccer boys," *~ 288 ~ Int. J. Phys. Educ. Sport. Heal.*, vol. 7, no. 6, pp. 288–292, 2020, [Online]. Available: www.kheljournal.com

[58] J. A. Landsheer and G. Den Van Wittenboer, "Unbalanced 2 x 2 factorial designs and the interaction effect: A troublesome combination," *PLoS One*, vol. 10, no. 3, pp. 1–18, 2015, doi: 10.1371/journal.pone.0121412.

[59] M. C. Siff, "Biomechanical foundations of strength and power training," *Biomech. Sport Perform. Enhanc. Inj. Prev.*, pp.

103–139, 2000.
[60] J. M. McBride, T. Triplett-McBride, A. Davie, and R. U. Newton, "The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed," *J. Strength Cond. Res.*, vol. 16, no. 1, pp. 75–82, 2002, doi: 10.1519/1533-4287(2002)016<0075:TEOHVL>2.0.CO;2.
[61] K. S. Park, "Nervous System," in *Humans and Electricity: Understanding Body Electricity and Applications*, Springer, 2023, pp. 27–51.
[62] C. J. Heckman and R. M. Enoka, "Physiology of the motor neuron and the motor unit," in *Handbook of clinical neurophysiology*, vol. 4, Elsevier, 2004, pp. 119–147.
[63] E. Manolopoulos, C. Papadopoulos, and E. Kellis, "Effects of combined strength and kick coordination training on soccer kick biomechanics in amateur players," *Scand. J. Med. Sci. Sport.*, vol. 16, no. 2, pp. 102–110, 2006, doi: 10.1111/j.1600-0838.2005.00447.x.
[64] C. Kurniawan, H. Setijono, T. Hidayah, H. Hadi, and S. Sugiharto, "The effect plyometric training with active-passive recovery for 8 weeks on performance physical abilities male judo athletes," *Pedagog. Phys. Cult. Sport.*, vol. 25, no. 6, pp. 361–366, 2021, doi: 10.15561/26649837.2021.0604.
[65] C. I. Karageorghis, "Team Sport Training and Performance," *Appl. Music Exerc. Sport*, pp. 177–198, 2020, doi: 10.5040/9781492595229.ch-008.
[66] Z. Radák, *The physiology of physical training*. Academic Press, 2018.
[67] A. Al Ameer, "The effects of plyometric and resistance training on selected fitness variables among university soccer-playing adults," *Ann. Appl. Sport Sci.*, vol. 8, no. 3, 2020, doi: 10.29252/AASSJOURNAL.817.
[68] M. Velmurugan and P Kulothungan, "Effect of circuit training and speed agility quickness training on motor fitness variables among school football players," *Kheljournal.Com*, vol. 3, no. 2, pp. 395–397, 2016, [Online]. Available: https://www.kheljournal.com/archives/2016/vol3issue2/PartG/5-4-30-308.pdf

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