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| RESEARCH ARTICLE

Effects of an 8-Week Plyometric Program on Acceleration, Power, and Change of Direction Speed (Using COD Deficit) on Elite Squash Players in Sri Lanka

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| ABSTRACT
High levels of agility, speed, response time, repeated muscle endurance, and both aerobic and anaerobic capacity are necessary for squash participation. There is a limited amount of standard traditional periodization to achieve optimal physical fitness for squash. Consequently, the goal of this research is to identify a more creative training design strategy. The purpose of this article aims to highlight the benefits of an 8-week plyometric program to help improve power, acceleration, and change of direction speed in elite squash players in Sri Lanka. Eleven elite squash players (age 20.81 ± 1.23 years; height 1.71 ± 1.59 m; weight 63.4 ± 4.11 kg) volunteered to participate. The plyometric program included three days per week for 8 weeks, including sets of 2 to 5 and 4 to 16 repetitions, with 2 to 5 minutes of rest for each plyometric exercise, in addition to their regular squash practice. Agility was assessed using the 505 Agility Test (505AT), while power performance was measured through the vertical jump (VJ) test and acceleration was measured through a 10 m sprint test, both before and after the training period. Change of Direction speed was calculated through COD deficit. Significant improvements for the vertical jump test, 505 AT, and 10 m sprint test (21.02 %, 20.32 %, and 16.68 % respectively) were noted after 8 weeks of the plyometric program and also, the change of direction speed was 13.39 % significantly improved. The 8-week plyometric program displayed significant improvement in power, and change of direction speed, suggesting that a method can be highly beneficial for squash players and coaches.

| KEYWORDS

Agility, High performance, Periodization, Squash

| ARTICLE INFORMATION

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1. Introduction

Being an excellent squash player demands a very high level of physical condition and is a very hard competitive sport. To compensate for high ball travel rates of up to 281.6 km/h, repetitive brief explosive actions requiring split-second decisions and responses necessitate great efficiency in agility, speed, and reaction time with regard to skill-related fitness components. In squash, where power is crucial, the capacity to accelerate and decelerate quickly over small distances is vital for success. According to (van der Kruk, van der Helm, Veeger, and Schwab, 2018), power is the rate at which work is completed or energy is transmitted to complete a task, or the capacity to apply maximum force quickly. Studies have indicated that peak strength has a significant impact on performance, with more accomplished athletes competing at higher levels across a range of sports than less accomplished athletes (Haff & Nimphius, 2012).

High proficiency in a range of areas, including muscular endurance, anaerobic and aerobic capacity, strength, power, speed, and agility, is necessary to play squash (Bennie & Hrysomallis, 2005). The intense nature of the sport can lead to rallies lasting 45 to 60 seconds with extremely short intervals in between, meaning that heart rates are often at an average of 190 bpm, with spikes over thresholds of 80% to 85% of the players anticipated maximum heart rate (Docherty, 1982). In a single five-set squash match, which may take anywhere from 60 to 90 minutes and require exceptional aerobic endurance, players can traverse up to 5000 meters.

There is not much research available on training strategies to achieve an elite level of physical fitness for squash. Different training phases in a linear periodization typically span 4–6 weeks and generally exhibit a consistent development with increasing intensities and decreasing volumes (Fleck, 2011). The high-performance top athletes in this case study had distinct neuromuscular adaptations that necessitated deviating from conventional training protocols. Periodization or program modification of some kind is necessary to guarantee that development is made over an extended period of time (Kraemer, Duncan, & Volek, 1998). There are obstacles to more advancement because of the shortcomings of conventional standard periodization (Issurin, 2010). With little scientific thought, more alternative approaches to training design have emerged in recent years.

Although low-volume single-set training programs do not provide strength gains in more highly trained athletes (Willoughby, 1993), our program gradually increases both volume and intensity. Elite athletes will differ greatly in terms of the percentage of different fiber types and the cross-sectional area of their muscles. If the stimulus is strong enough, it is possible to change the properties of skeletal muscle (Kraemer, Duncan, & Volek, 1998). In order to help professional squash players in Sri Lanka increase their acceleration and change of direction speed, this article will emphasize the advantages of an 8-week plyometric program.

2. Methodology

2.1 Participants

For this study, eleven elite squash players volunteered to take part (n = 11; average age 20.81 ± 1.23. years; average height 1.71 ± 1.59 m; average weight 63.4 ± 4.11 kg) and all participants were national players who underwent training in speed, specific court movements, and mobility training in tennis practice six times a week for 60 minutes. They were in good health, had no history of lower body injuries, and did not have any medical or orthopedic issues. Before gathering data, the participants were informed about the study's benefits and potential risks, and they provided written informed consent to participate.

2.2 Plyometric program and design

The plyometric training program (Table 1) was conducted three times per week for a duration of 8 weeks, taking place on Mondays, Wednesdays, and Fridays. The intensity of the training was progressively increased, starting from low to medium during the first 5 weeks and then reaching a high intensity in the last 3 weeks. Plyometric training program training volume and intensity were based on the recommendations by Miller, Herniman, Ricard, Cheatham, and Michael (2006) and Gamlath, & Thotawaththa, (2023).

Table 1. *Plyometric eight-week training program*

Training Weeks	Training Volume (Foot Contacts)	Plyometric Drills	Set x Reps	Training Intensity
Week 1	92	Side to Side Hops	2 x 16	Low
		15 cm Hurdles Jump (Both legs)	3 x 12	Low
		20 cm Box Jump	2 x 12	Low
Week 2	104	Side to Side Hops over 15 cm Barrier	2 x 10	Low
		20 cm Hurdles Jump (Both legs)	3 x 10	Low
		20 cm Box Jump	2 x 12	Medium
		Standing Long Jump	5 x 6	Medium
Week 3	120	Side to Side Hops over 15 cm Barrier	2 x 10	Low
		20 cm Hurdles Jump (Both legs)	3 x 10	Low
		15 cm One Leg Box Jump	2 x 8	Medium
		Standing Long Jump	5 x 6	Medium
		30 cm Box Jump	4 x 6	High
Week 4	134	Side to Side Hops over 15 cm Barrier	2 x 10	Low
		20 cm Hurdles Jump (Both legs)	3 x 10	Medium
		15 cm One Leg Box Jump	4 x 8	Medium
		Standing Long Jump with Lateral Sprints	5 x 4	High
		30 cm Box Jump	4 x 8	High

Week 5	130	Side to Side Hops over 15 cm Barrier 20 cm Hurdles Jump (Both legs) 15 cm One Leg Box Jump Standing Long Jump with Lateral Sprints 30 cm Box Jump Lateral Jump Single Leg	2 x 10 3 x 10 2 x 8 5 x 4 4 x 8 2 x 6	Low Medium Medium Medium High High
Week 6	130	Side to Side Hops 15 cm Hurdles Jump (Both legs) 20 cm Box Jump Hexagon Drill Double Leg Hop	3 x 12 3 x 10 2 x 12 2 x 12 2 x 8	Low Medium Medium Medium High
Week 7	128	Side to Side Hops 15 cm Hurdles Jump (Both legs) 20 cm Box Jump Hexagon Drill Double Leg Hop	2 x 12 3 x 10 3 x 10 2 x 12 2 x 8	Low Low Medium Medium High
Week 8	118	Side to Side Hops 15 cm Hurdles Jump (Both legs) 20 cm Box Jump Hexagon Drill Double Leg Hop	2 x 12 3 x 10 2 x 12 2 x 12 2 x 8	Low Low Medium Medium High

Each exercise was performed with sets ranging from 2 to 5, and repetitions ranging from 4 to 16, with a rest period of 2 to 5 minutes between each set. The training sessions lasted 15-20 minutes and were incorporated into the regular squash fitness practice for the selected sample. Participants were instructed to give their maximum effort during each training session.

Throughout the 8-week intervention period, the sample group continued their usual squash training, while refraining from any other training activities such as resistance training or additional plyometric exercises that could influence the study results. Pre- and post-training assessments included tests for the 505-agility test, 10 m sprint test, and vertical jump to measure the effects of the training program and change of direction deficit.

Change of Direction Deficit calculation

COD Deficit 505(%) = [(Time 505 – Time Sprint 10 m) / Time Sprint 10 m] x 100 (Freitas et l, 2021)

2.3 Dependent Variables

In order to assess the impact of plyometric training on Acceleration and change of Direction deficit, four specific tests were conducted: the 505-agility test, 10 m sprint test, and vertical jump test. Before the initial testing session, each player underwent a familiarization process with the testing protocol to ensure they understood the procedures. To maintain consistency and standardization in testing, the same trained test leaders administered the entire set of tests, following an identical order and protocol for all participants. Prior to the testing phase, the subjects engaged in a 10-minute warm-up routine, which included sub-maximal jogging and active stretching to prepare their bodies for the evaluations. To allow sufficient recovery between each test, a 5-minute rest period was provided. This ensured that participants were physically ready for each subsequent test, avoiding any potential fatigue that could affect the results. The careful implementation of these standardized procedures aimed to minimize any confounding variables and enable a reliable assessment of the effects of plyometric training on agility and power among the participants.

505 Agility test: In this test, players are tasked with completing the distance between two markers placed 15 meters apart in the quickest time possible. A computerized timing gauge system will be positioned at the tenth meter to accurately measure time. Participants aim to achieve maximum acceleration from the starting line to the timing gate located at the 10-meter mark. They then stop behind the line of the second marker, execute a 180-degree change in direction, and accelerate once more towards the finish line, which is positioned 5 meters away. The total distance covered in this drill is 20 meters, consisting of a 10-meter run-up and two 5-meter distances (Freitas et l, 2021).

10 m Sprint test: This test was to accurately measure sprint times; electronic timing gates were employed in the sprint test. The test took place on a grass surface, with the timing gates precisely positioned 10 meters away from a predetermined starting point. Participants were instructed to sprint with maximum speed along the 10-meter distance from the starting line. Speed measurements were recorded with a precision of 0.01 seconds, and the fastest time out of three trials was considered as the final result.

All individuals performed baseline agility testing prior to commencing the training program, which included the three aforementioned tests. The entire testing process, which included a warm-up phase, ten-minute rest breaks between tests, and roughly three minutes of respite in between repetitions, lasted about an hour per participant. To ensure that participants understood the testing processes, thorough explanations and demonstrations of each test were given. Furthermore, practice tests were conducted to acquaint participants with the testing protocols (Cooke, Quinn., & SibteN , 2011, Lockie, Murphy, Knight, & De Jonge, 2011).

The tests were counterbalanced in both the pre-and post-testing sessions to mitigate any potential biases in the testing procedure. For a more accurate evaluation of performance, each test was administered three times, with the results averaged (Di Mascio, Ade, Mushan, Girard, & Bradley, 2020).

Vertical jump: In this study, the participants assumed a side-on position, facing a wall, and raised their arms closest to the wall to their maximum height. While keeping their feet firmly planted on the ground, the participants' fingertips were marked at this standing reach height. To begin the jump, the participants bent their knees to approximately a 90-degree angle. They then executed a vertical leap, utilizing both their arms and legs to propel their body upward. The main goal was to touch or leave a mark on the wall at the highest point reached during the jump. The difference between the standing reach height and the jump height was measured and recorded, with the best out of three attempts being documented for each participant. It's important to note that this particular study employed measurements of single-leg vertical jumps [Holcomb, 1996, Saez, 2008].

3. Results and Discussion

There were significantly higher rates of improvement in acceleration and power compared to change of direction speed. Pre-post comparison results can be seen in Figure 1, Figure 2, Figure 3, and Figure 4.

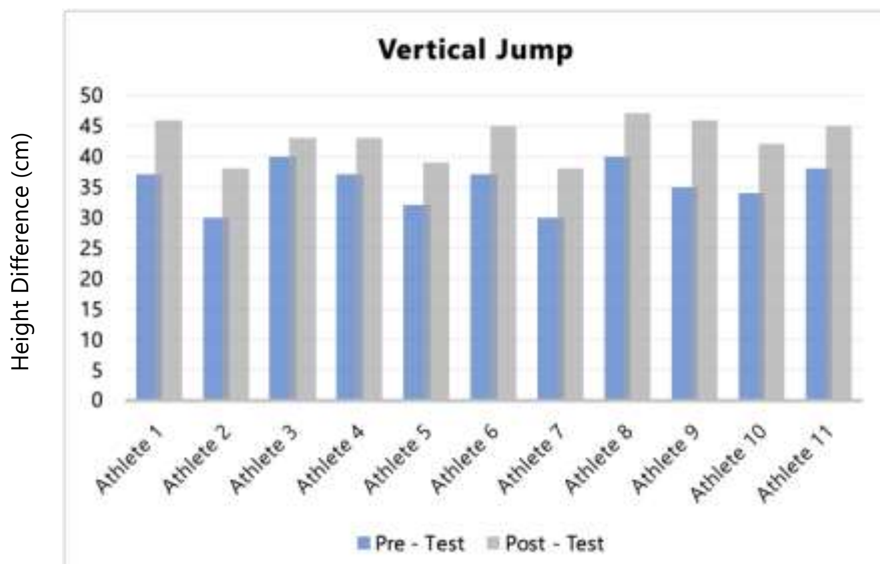

Figure 1. *Pre - and Post - Test results Comparison of the Vertical Jump*

Little is known regarding the exact training protocol for elite squash athletes. The aim of this study was to observe and interpret the results of an 8-week plyometric training regime on elite squash athletes. The results of our program show that there is a significant increase in post-testing performance for all 11 athletes as compared to their pre-test results. For the Vertical Jump test, athletes improved at an average of 21.02 %, 505 – Agility Test showed an average improvement of 20.32 %, the 10 m Acceleration test exhibited an improvement of 16.68 %, and the COD Deficit reduced by 13.39 % for all 5 participants. Participants show all-around change of direction speed improvements in the agility test.

This development validates the original theory that suggests distinct plyometric program variants are needed for elite athletes in order to assure longer-term success (Kraemer, Duncan, & Volek, 1998). The growth in volume defies the conventional linear periodization program's observation, which is that the volume taper off as the program goes on. According to a study by Häkkinen, Pakarinen, Alén, Kauhanen, and Komi (1988), the amount of absolute strength gains relative to the untrained will be restricted for individuals who have already established a higher pretraining status, or high-performance athletes. Elite athletes improve their performance through higher quantities of training stimulus, which might be difficult to get by traditional training, in contrast to amateurs and medium-level athletes who just need minimal training stimulus to excel (Issurin, 2010).

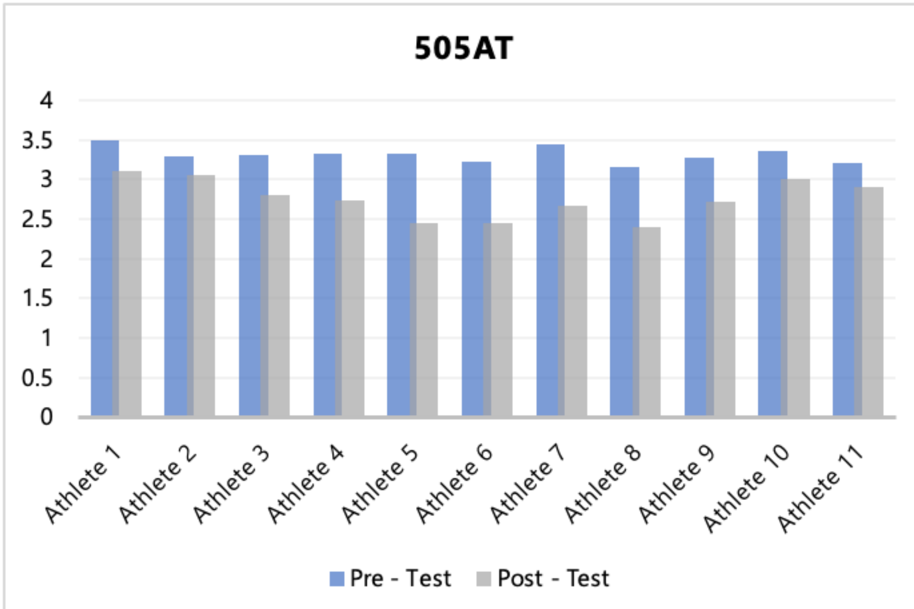

Figure 2. *Pre - and Post - Test results Comparison of the 505 Agility Test*

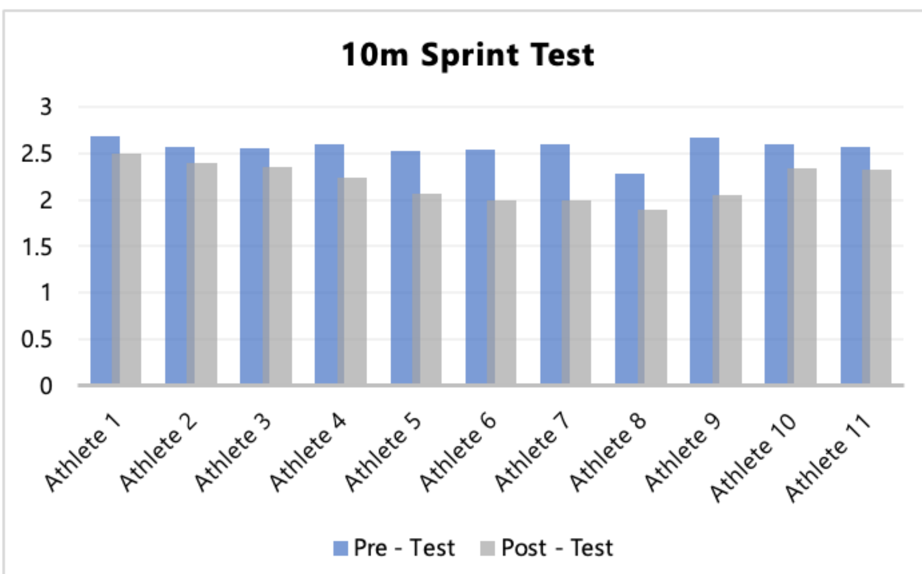

Figure 3. *Pre - and post-test results comparison of the 10 m Sprint Test*

To help their athletes reach peak performance, coaches and applied sport scientists in elite sports are always looking for and implementing cutting-edge training techniques and effective tactics (Gouttebarge, Moen, Boschman, & Kantebeen, 2013 & Thotawaththa, & Chandana, 2023). Coaches and sport scientists must regularly assess the effects and consequences of training methods through the use of the proper training protocols in order to maximize the effectiveness of training. Frequent testing and assessment yield input to coaches and athletes that can be utilized to pinpoint an athlete's weaknesses and modify training regimens to strengthen those areas. Athletes may continue training ineffectively without this input and fail to acquire the fitness, abilities, tactical awareness, and other capacities required for successful competition (McAuliffe, 2010).

Looking back at the data, it can be seen that every athlete improved in their post-test scores, demonstrating the program's efficacy and supporting earlier research on elite-level adaptations. Essentially, rather than utilizing more ostentatious methods like High-Intensity Interval Training (HIIT), coaches can experiment with training changes of certain basic features, such as volume. According to a study by Rynecki, Siracuse, Ippolito, and Beebe (2019), the rise in interest in HIIT between 2012 and 2016 resulted in a 144% increase in injuries affecting both lower and upper body extremities. However, Sport Specific Injury Prevention Training (SSIPT) was specifically included in the program and demonstrated that there were no injuries sustained by the athletes during or after the program. Increases in electromyographic EMG amplitude and rate of EMG activation show changes in the pattern of neural drive ($P < 0.05$), which supports the notion that sport-specific resistance training improves neuromuscular adaptation (Judge, Moreau, & Burke, 2003).

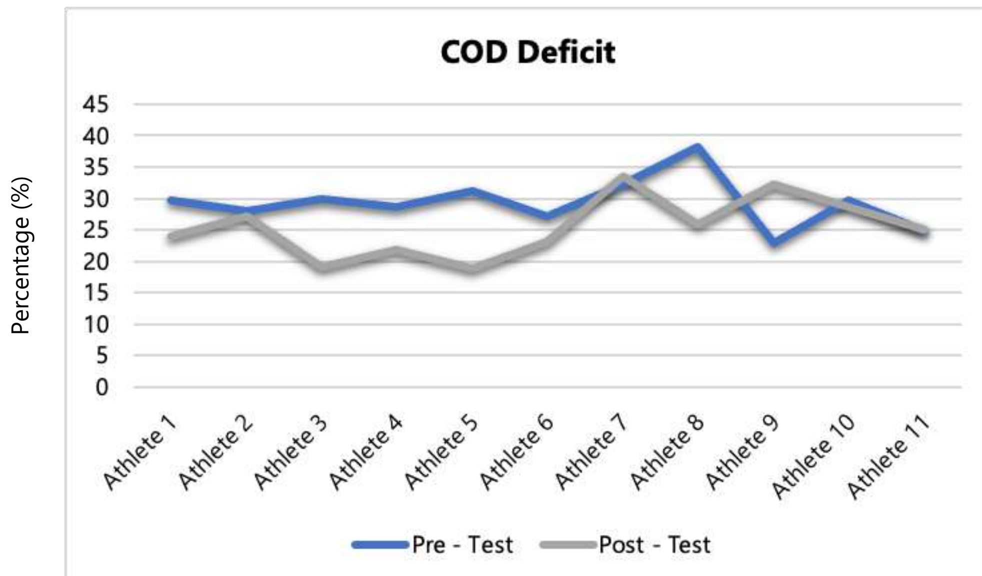

Figure 4. *Pre - and Post - Test results Comparison of the Change of Direction Deficit*

Sport Specific Injury Prevention Training (SSPIT) was applied in the training intervention, and there were no injuries among the athletes throughout or after the program. Increases in electromyographic EMG amplitude and rate of EMG activation show changes in the pattern of neural drive ($P < 0.05$), which suggests that sport-specific plyometric training improves neuromuscular adaptation (Judge, Moreau, & Burke, 2003).

This study indicates that our 8-week plyometric program's methodology is successful in helping elite squash competitors achieve their goals. Owing to the shortcomings of a typical, traditional periodization that makes it harder for elite athletes to advance, variance must be taken into account (Issurin, 2010). This study provides recommendations for future research and training iterations that will be put into practice. Several more comprehensive studies with different training regimens are required in the hopes of establishing a baseline that athletes and coaches may use. Increasing the sample size may be helpful in obtaining more accurate and trustworthy data with sufficient statistical power to yield findings that more closely represent the truth. Determining the disparities in gender adaptations may also benefit from comparing male and female squash athletes.

4. Conclusion

The findings of this study provide strong evidence supporting the benefits of plyometric training for enhancing acceleration and change of direction speed in athletes. The results demonstrate that plyometric exercises not only add variety to training routines but also contribute to improved strength, explosiveness, and overall agility. Remarkably, significant improvements in agility were observed within a relatively short timeframe of eight weeks, making plyometric training a valuable addition to the final preparatory phase before in-season competitions for athletes. This emphasizes the importance of considering the impact of other training modalities when evaluating the effectiveness of specific interventions. Moreover, this study successfully addresses the gap in understanding the change of direction deficit in Sri Lankan Squash players. This knowledge can guide the development of targeted training strategies and customized interventions to enhance COD speed and optimize performance in squash players. Further research should explore the long-term effects of plyometric training and establish optimal training protocols tailored to specific sports and athlete populations. Such investigations would provide deeper insights into the sustainability and individualized implementation of plyometric interventions in athletic training.

In conclusion, the results of this study underscore the potential of plyometric training to improve power and agility and change of direction speed using the COD Deficit calculation. It is recommended that coaches incorporate plyometrics into the competitive phase for young athletes, as this type of training has been shown to be effective in enhancing performance. Given that coaches and athletes often have limited time during the collegiate or competitive season, plyometric training can offer significant benefits in a relatively short period.

The study suggests that future research must focus on the long-term effects of plyometric training beyond the 8-week period used in this study. A more extended study could provide valuable insights into the sustainability of improvements in acceleration, power, and change of direction speed. This information could help coaches and athletes to better understand the duration of training required to maintain performance gains. It is essential to explore sport-specific plyometric training protocols for elite athletes in other sports or even within different skill levels of squash players. Customized plyometric programs tailored to the unique demands of specific sports and individual athlete characteristics could further optimize training effectiveness. Conduct comparative studies to evaluate the effectiveness of plyometric training against other popular training modalities. Understanding how plyometrics compares to resistance training, agility drills, or other specialized exercises can help coaches make informed decisions about the most suitable training methods for their athletes. It is also necessary to explore the physiological and neurological adaptations associated with plyometric training. Investigate changes in muscle activation patterns, neuromuscular coordination, and energy system utilization to gain a deeper understanding of the mechanisms underlying the observed improvements in acceleration, power, and change of direction speed.

The study may have limited generalizability due to the small sample size of elite squash players from Sri Lanka. A larger and more diverse sample could enhance the external validity of the findings and provide a better representation of the broader athlete population.

The absence of a control group in the study design makes it challenging to attribute the observed improvements solely to the plyometric intervention. Including a control group would help control for confounding variables and provide a more robust basis for causal inference.

The study might not have accounted for external factors, such as environmental conditions, athlete motivation, or adherence to the prescribed training program. These variables could influence the outcomes and limit the study's ability to isolate the effects of plyometric training.

Some of the outcome measures, such as agility, may have relied on subjective assessments. Integrating objective measures, like motion capture or force plate analyses, could enhance the precision and reliability of the results.

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