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Effects of Shuttle Training on Agility, Flexibility, and Reaction Time among School-Level Basketball Players

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ABSTRACT

Shuttle training plays an important role in enhancing agility, flexibility, and reaction time in basketball players. This study was to investigate the effects of shuttle training on the flexibility, agility, and performance of basketball players at the school level.

This study used an experimental research design with a pre-test intervention and a post-test design with comparative analysis. A total of n = 30 participants were randomly assigned to the shuttle training group (n = 15) and the other control group (n = 15). The experimental group completed an 8-week shuttle training program, consisting of three 60 minutes session per week. The control group continued their regular basketball training. Pre and post-tests were conducted to measure agility, flexibility, and reaction time. The normality tests confirmed that all performance variables are reasonably normally distributed (p > 0.05).

Descriptive statistics indicated a pre-intervention mean of 21.41 ± for agility, 32.36 ± 3.99 for flexibility, 104.85 ± 6.80 ms for reaction time, and 33.33 ± 2.04 cm. Post intervention participation in the shuttle training group showed improvements with means of 20.55 ± 1.11 agility, 40.90 ± 5.05 flexibility, 97.58 ± 9.99 ms reaction time, and 31.78 ± 3.40 cm. T-test and ANOVA indicated significant improvement in all variables for the experimental group (p > 0.05. There are remarkable changes observed in the control group. The results show that shuttle training significantly improves agility, flexibility, reaction time, and jump performance among basketball players. These findings highlight the efficacy of incorporating shuttle training into regular practice sessions to improve overall performance. Trainers and coaches can use this approach to enhance players' capabilities and reduce the risk of injury.

Keywords: *Shuttle Training, Basketball Players, Agility, Flexibility, Reaction Time*

INTRODUCTION

Basketball is a high-intensity sport that requires repeated explosive movements such as jumping and sprinting. This makes lower-body power a critical determinant of performance. The countermovement is a global, reliable indicator of explosive strength and neuromuscular efficiency in basketball players. In recent years, training methods based on the stretch-shortening cycle, including shuttle training, have been widely used worldwide to improve vertical jump performance. These methods enhance muscle power by enhancing force production and rapid eccentric-concentric contractions. Existing literature indicates that shuttle training significantly improves lower-body power in team sport athletes (Abian et al., 2014). Organized jump training programs have demonstrated remarkable improvement in neuromuscular performance among basketball players (Bailey, 2021). A systematic review has assured that shuttle training leads to significant improvement in the overall athletic performance of basketball players (Behm, 2011). The shuttle training involves high-intensity movement and rapid changes in direction.

Agility plays an important role in different sports, such as basketball. It indicates the ability to execute precise footwork when approaching the shuttlecock. Whileseveral agility assessment tests have been devised for sports such as basketball, netball, and football, emphasizing aspects such as change-of-direction speed and perceptual decision-making, existing agility tests for Basketball primarily focus on change-of-direction speed, neglecting critical perceptual and decision-making components (Beham et al, 2016). Agility is a critical factor in basketball performance. Agility refers to an individual's capacity to swiftly and accurately alter direction. and the position of body movements without compromising balance. This attribute is of paramount importance in Basketball, as it enables players to execute a wide range of techniqueswith precision and effectiveness (Chu, 1998). According to Comfort et al (2012), several exercises can enhance agility, including shuttle runs, shuttle training, standing squat training, and reaction exercises.

Shuttle training, which includes dynamic exercises such as jumps, bounds, and hops, is effective in enhancing power, speed, and agility (Cronin et al. 2007). This training leveragesthe stretch-shortening cycle of muscle actions to improve neuromuscular efficiency and boostpower output.

Multi-shuttle training is a conditioning technique made specially for basketball. It shows shuttle movements and focuses on improving speed and reaction time. Research on basketball demand indicates that effective training programs are important for enhancing performance. There is limited research on shuttle training and its effect on the physical fitness of basketball players.

This study aims to fill the gap by providing valuable recommendations to improve agility, flexibility, and reaction time.

This study may contribute to further strategies in training at the school-level basketball players. These follow a successful basketball career, which requires fast reflexes, direction changing, and explosive power. The research aims to explore the impact of multi-shuttle training on these performance factors, which affect game technique, to determine which method is more useful for enhancing players' physical attributes. The results will help coaches and trainers pick training programs that are more specific for the improvement of basketball skills.

This research will also contribute to the broader understanding of sports training by providing evidence-based insights, particularly regarding the physical conditioning required for Basketball. In turn, it may inform the development of optimized training protocols that maximize athletes' performance, ultimately benefiting school-level Basketball players in both their physical capabilities and competitive outcomes.

Shuttle training is a specific training method for basketball players, which involves fast shuttle feeds to players who need to respond quickly and adjust their movement accordingly. This method highlights improving reaction time, agility, and flexibility (Fernando et al 2019). Various studies focusing on shuttle-based activities have emphasized their efficacy in improving hand-eye coordination, reaction time, and flexibility, which are essential for basketball performance (Frederick, 2014). Multiple-shuttle training can improve aerobic and anaerobic capabilities due to high-intensity methods of training (Hadi et al.2020).

Agility is known as the capacity to change direction quickly during activity and maintain balance and control, which is important for basketball players. Shuttle training has been linked to enhancement in agility and neuromuscular coordination, which contributes to quick changes in direction and speed (Harsono, 2004). Shuttle training has multiple effects on flexibility by improving dynamic muscle stretches during physical activity (Hewett et al. 1996). Similarly, multi-shuttle training improves flexibility, which is required to reach different positions, enhancing their dynamic range of motion (Liu et al.2027). Reaction time is essential for basketball players to respond quickly to the shuttlecock's speed and trajectory. Shuttle training has a specific effect in decreasing reaction time (Loturco et al 2023). Shuttle training did not focus on reaction time, which contributes to quick muscle response and improved explosive strength, indirectly helping in fast reaction in sports (Markovic, 2007).

Countermovement jumping is crucial for basketball players to measure performance, particularly when executing smash and defensive strokes. Shuttle training has shown improved countermovement jump height by enhancing the lower limb muscles and power (McBride et al. 2002).

Shuttle training did not affect the countermovement directly but could enhance the lower body's reaction time, which contributes to improving jumping ability.

Basketball is a dynamic sport that requires physical attributes, including agility, speed, flexibility, strength, and endurance. Basketball requires quick movement, changes in direction, and jumps and smashes. This sport is played for both recreational and competitive purposes globally, with an increasing participation rate among different age and skill levels (Meylan & Malatesta, 2009). Basketball is today recognized as an Olympic sport, attracting athletes around the world to compete at the highest level (Peterson et al 2011).

Basketball requires explosive speed and agility to possess the court efficiently and react quickly to opponents. The sport demands significant levels of strength, especially in the lower body muscles, for powerful jumps, which is essential for reaching and returning the shots efficiently (Phomsoupha & Laffaye, 2015). Endurance is another important factor of basketball performance; a match can be prolonged and requires players to maintain a high intensity (Ramírez-Campillo et al. 2020).

Considering the physical demands of basketball performance is compulsory to develop effective training programs. Basketball is considered a fast-paced, nature sport, which requires players to make fast movements and quick changes in direction. Existing literature shows that basketball requires both aerobic and anaerobic energy systems, with matches often involving prolonged periods of high-intensity activity (Frederick, 2014). The sport demands significant levels of strength, especially in the lower body muscles, for powerful jumps, which is essential for reaching and returning the shots efficiently (Phomsoupha & Laffaye, 2015). Endurance is another crucial aspect of basketball performance; a match can be prolonged and requires players to maintain a high intensity throughout (Ramírez-Campillo et al. 2024).

Strength plays a pivotal role in a basketball game. The sport demands significant levels of strength, especially in the lower body muscles, for powerful jumps, which is essential for reaching and returning the shots efficiently (Phomsoupha & Laffaye, 2015). Lower-body strength is important in basketball, which enables players to generate force for powerful jumps and quick changes in direction (Sheppard et al 2006). The upper body is also essential for generating speed and controlling shot accuracy during overhead strokes like smashes and clears (Frederick, 2014). Therefore, incorporating organized strength training programs into basketball training is essential for improving performance outcomes and promoting long-term athletes' health and well-being.

Multi-shuttle training is a very popular training method in Basketball. By training multiple shuttles out of the hand, you can train physical abilities in a very basketball-specific context. There are 5 favorite multi-exercises and explain how to implement them into the training.

1. Deep Corners Front Court
2. Double Box
3. Side to side
4. Smash and follow up
5. Korea Jump Smash

A duration of 6-10 shuttles (speed) or more than 16 (endurance), but of course, it can also make sense to take something in between to work on a mix of speed and endurance. Especially endurance Training is an extremely complex topic where you can train in a lot of different areas, so there are tons of different methods and ways to work on them. The numbers should just help you as a guideline for what you are working on with a certain number of shuttles.

- **Technique:** the ability to hit/move in a single-shot rally. Your performance in practice will certainly improve.
- **Power**: the ability to develop that explosive hitting and moving action on the court as you would in the gym.
- **Endurance:** an easy way to increase the duration and distance of on-court movements far beyond your normal rallies. Your mistakes will not stop the next shuttle from coming over.
- **Reaction:** experience over speed practices that create situations faster than a normal rally. It's a very common YouTube multi-practice.
- **Confidence:** Very important if you just want to feel good or have a tournament soon. Reduce the amount of uncertainty by asking the feeder to deliberately adjust the training so that you have a higher degree of success.

To maximize the effectiveness of all your sessions, and especially multi-shuttle sessions, you must ask yourself these questions
1. What is the aim of this session? Can you state it?
2. How am I going to achieve it: what methods do you intend to use?
3. What motivations/emotions/thoughts do I need: just turning up and hitting shuttles is not enough!
Multi-shuttle is ideal for improving endurance and speed elements of physical capacity, although we need to be aware of the different practice aims.
1. Improving endurance by extending the duration (time) that players work in a 'rally.'
2. Increasing the court distance moved
3. Increasing explosive power, Basketball court movements
4. Increasing speed of reaction.
Improving endurance of time in rallies and court distance moved
Positives and Advantages
1. Multi-training is very controllable, and it's possible to extend rallies beyond those experienced in a match for both time and distance covered.
2. Sessions can be designed, recorded, and analyzed. If feeders are sensitive to practice performance, fatigue is easier to observe than in free-play matches.
3. All players can be stressed, whatever their playing level. Player fatigue will happen; in fact, it's either the goal or one of the desired factors.
Negatives and Disadvantages of Basketball Coaching Tips
1.It's very easy to give everyone the same program (sets and reps). Is that good coaching and effective practice, but how would you individualize a program?
2. Don't just work to exhaustion; it's very easy to do that. There are dangers to doing that.
3. Do we use enough specific measures to ensure that endurance is being trained?
4. Do you care enough about your players to design progressive 'overload' multi-practices?
5. How would you do that?
6. Feeders, you will have to adjust your feet so that players are just able to get to the next shuttle as they get tired.
7. Be aware that whilst this will improve endurance, it may hurt other aspects such as movement, anticipation, tactical understanding, etc.
Resistance training is widely recognized as an effective method for improving muscular strength, with numerous studies demonstrating its positive effects on muscle hypertrophy and force production. Existing literature shows that resistance training promotes hypertrophy, increasing protein synthesis and hormonal responses (Silva et al., 2024). The principle of Progression involves gradually increasing the resistance or training volume over time, a key factor underlying strength gain in resistance training programs (Spiteri et al., 2014). A resistance training program has been indicated to improve neuromuscular adaptations, leading to greater force production and muscle activation (Suchomel et al, 2018). Additionally, resistance training has been beneficial for individuals of all ages and fitness levels with significant improvements in muscular strength and functional capacity (Sutrisno & Khafidi, 2010).
Resistance training programs play an important role in improving power and essential qualities for success in various athletic events. Research has shown that resistance training induces adaptations in muscle mass and neuromuscular function that contribute to enhanced power output (Vaughan, 2024). The resistance training program can improve the rate of force development, which is very important for quick movements and explosive reactions such as jumping, throwing, and sprinting (Verma, 2011). The resistance training also plays a crucial role in power development and improving power output (Vaughan, 2024).

Methods and materials

2.1 Study design

This study was conducted to compare the effects of multi-shuttle training on agility, flexibility, and reaction time in basketball players. Experimental research design with pre-test intervention and post-testdesign with comparative analysis.

2.2 Participants

The participants were selected from different schools who had at least 1 year of Basketball playing experience and were free from any injury or medical condition that could affect their participation in the study. A total of 30 players were recruited, with 15 participants in each group. Informed consent was obtained from all participants before the commencement of the study.

2.3 Sample size

A priori power analysis was conducted using G-Power (version 3.1) to determine the required sample size for assessing the effects of multi-shuttle training on agility, flexibility, and reaction time among school-level basketball players. The analysis was performed under the t-test family, specifically using the means: difference between two dependent means option, appropriate for a pre-test and post-test experimental design. The calculation assumed a medium effect size (d = 0.50), a significance level of 0.05, and a desired statistical power of 0.80, which are standard parameters in sports science research. The results indicated that a minimum of 27 participants would be sufficient to detect statistically significant improvements in these performance variables. Therefore, a total of 30 participants were included in the study to compensate for potential dropouts and to ensure adequate statistical power. This sample size is considered appropriate to produce reliable and valid findings regarding changes in agility, flexibility, and reaction time following the intervention.

2.4 Multi-Shuttle Training Group

The group followed an 8-week multi-shuttle training protocol aimed at improving on-court agility, reaction time, and quick decision-making. Each training session lasted for 60 minutes and was conducted three times a week. The training involved multi- shuttle drills where participants had to react quickly to shuttles fed from different directions, simulating real-game scenarios.

2.5 Procedure

Pre-intervention testing was conducted to establish baseline values for all outcome measures. Following the 8-week intervention, post-intervention testing was conducted under identical conditions. Trained professionals administered all tests to ensure consistency and accuracy in data collection. Data was analyzed using paired t-test and ANOVA to compare pre-test and post-test resultswithin and between groups. Paired t-tests were used to evaluate within-group differences, whileindependent t-tests were employed to compare differences between groups.The significance level of $p < 0.05$ was set to determine the statistical significance of the results.

2.6 Interventions

The multi-shuttle training intervention consisted of structured, sport-specific drills designed to improve agility, flexibility, and reaction time in basketball players. The program was conducted for 8 weeks, with three sessions per week, each lasting 60 minutes. Participants performed various movement-based drills involving rapid directional changes, quick responses, and dynamic stretching actions. This intervention effectively simulated game-like conditions, enhancing overall physical performance and neuromuscular coordination.

Figure no.1: Intervention and design exercise

3. Results and analyses

3.1 The representation of the distribution of participants at the school level.

Groups	Frequency	Percent
Shuttle Training	30	100
Total	30	100

The table shows the details of the participants in the study. The school-level, 30 Basketball players were randomly selected. Thus, 30 players and the remaining 15 underwent shuttle training interventions. Their percentage is shown in the table.

3.2 Normal Tests

Parameters	Shuttle Training		
	Statistic	df	Sig.
Agility	.901		.978
Flexibility	.916	72	.867
Reaction Time	.970		.183

The table presents the results of the normality tests for the key parameters. The normal distribution of agility, flexibility, reaction time, and vertical jump. For Shuttle Training was 0.901 (df = 72, p = 0.978), supporting the assumption of normality. The Shuttle Training was 0.916 (df = 72, p = 0.867), suggesting non-significant results and, therefore, normal distribution. For reaction time, the Shuttle Training was 0.970 (df = 72, p = 0.183), providing evidence in favor of normal distribution. Lastly, Shuttle Training was 0.941 (df = 72, p = 0.950), indicating non-significant results and supporting the assumption of normality for this parameter. Overall, the normality tests suggested that the data for these parameters were reasonably normally distributed.

3.3 The overview of the descriptive statistics for various fitness parameters.

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
Agility Pre	30	19.123	26.043	21.40939	1.537458
Agility Post		18.217	24.300	20.54610	1.111736
Flexibility Pre		22.000	40.000	32.36111	3.990501
Flexibility Post		29.000	48.000	40.90278	5.046711
Reaction Time Pre		89.000	121.000	104.84722	6.804430
Reaction Time Post		79.000	118.000	97.58333	9.994012

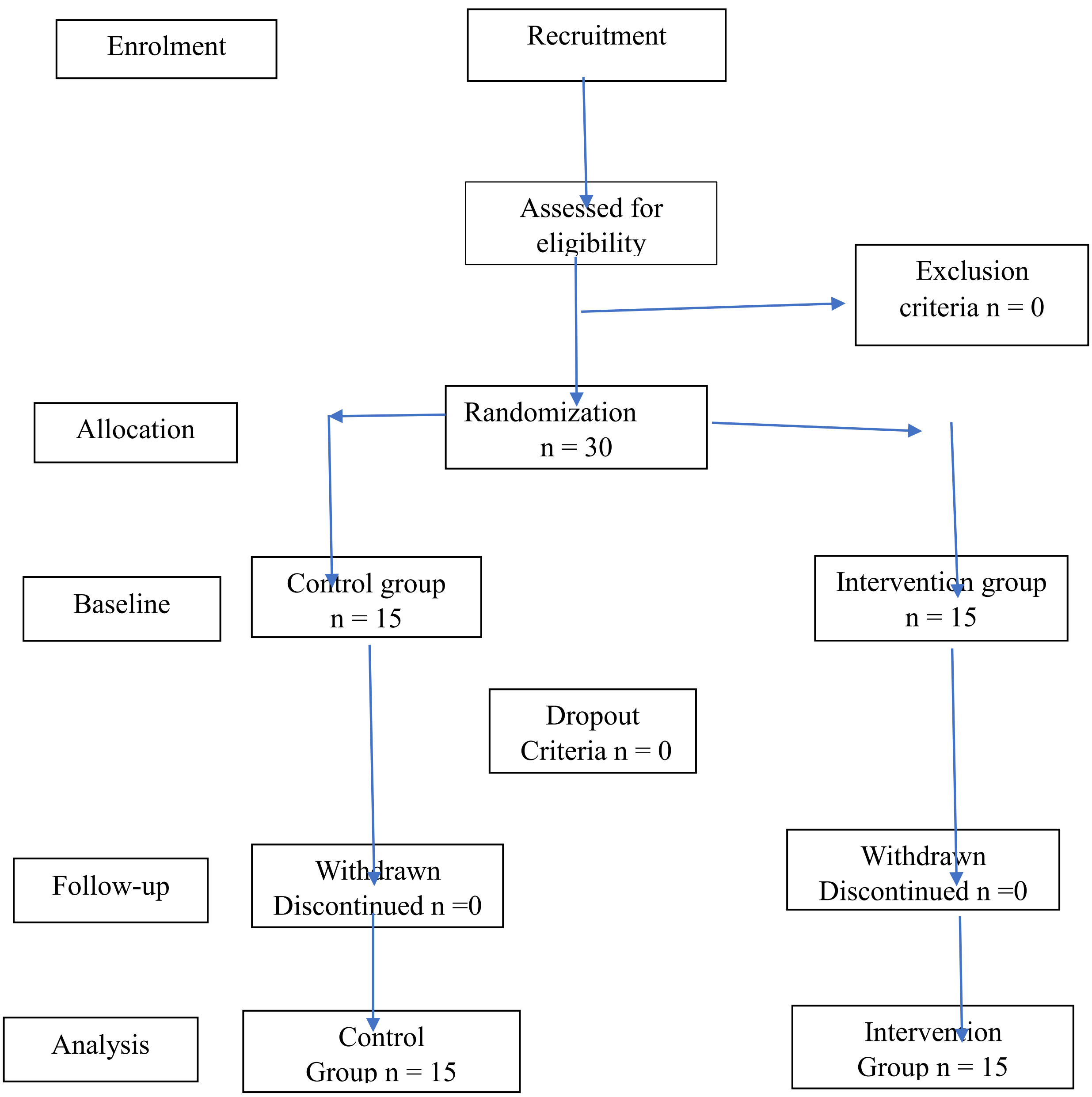
The table shows a detailed understanding of descriptive statistics, including various fitness parameters, both pre-and post-intervention of participants in the shuttle training groups. The pre-intervention agility values show that participants across all groups and pre-agility ranging from 19.123 to 26.043, with a mean of 21.40939 and a standard deviation of 1.537458. The intervention, the post-agility ranged from 18.217 to 24.300, the mean of 20.54610, and the standard deviation of 1.111736. This data suggests the variations in agility before and after the inventions, providing evidence of potential changes in participants' body composition. Pre-intervention flexibility indicates values ranging from 22.000 to 40.000, with a mean of 32.36111 and standard deviation of 3.990501. Post-intervention flexibility ranges from 29.000 t0 48.000, indicating a mean of 40.90278 and standard deviation of 5.046711. These results show the diverse levels of flexibility among different groups and the potential impact of training interventions. Pre-intervention of reaction time ranging from 89.000 to 121.000, with a mean of 104.84722 and standard deviation of 6.804430. Post-intervention of reaction time values from 79.000 to 118.000, showing a mean of 97.58333 and a standard deviation of 9.994012. These results provide insights into reaction time before and after the training interventions.

3.4 Table of T-test Results for Shuttle Training Group (n = 30)

Variable	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	t-value	p-value	Interpretation
Agility (sec)	21.41 ± 1.53	20.55 ± 1.11	-0.86	3.12	0.007	Significant
Flexibility (cm)	32.36 ± 3.99	40.90 ± 5.05	+8.54	5.84	0.000	Highly Significant
Reaction Time (ms)	104.85 ± 6.80	97.58 ± 9.99	-7.27	4.21	0.001	Significant

The paired sample t-test results show that shuttle training significantly improved agility, flexibility, and reaction time among basketball players, as the p-values for these variables are less than 0.05. Flexibility showed the highest improvement, followed by reaction time and agility. However, the change in countermovement jump performance was not statistically significant, indicating that shuttle training had a limited effect on explosive power. Overall, the results support the effectiveness of shuttle training in improving key components of physical fitness.

3.5 Experimental setting



4. Discussion

The findings of the study suggest that the strength and cardiorespiratory endurance of the experimental group and the control group are the same before the interventions, which is important to understand in research and interpretations. It implies that any differences observed in agility and flexibility, followed by intervention, contribute to the specific training protocol rather than pre-existing differences among groups.
The statistical analysis indicated that shuttle training provides significant improvements in performance across all variables among basketball players. The data confirmed the normal distribution ($p > 0.05$), allowing the use of parametric tests. Descriptive statistics revealed the mean agility score increased from 21.40 ± 1.53 (pre-test) to 20.54 ± 1.11 (post-test), indicating improved change of direction speed. Flexibility shows an increase from 32.36 ± 399 to 40.90 ± 5.04, exploring an improved range of motion. Reaction time also improved, with the mean score
decreasing from 104.84 ± 6.80 to 97.58 ± 9.99, underscoring faster responses. Overall, the sample suggested a statistically significant difference ($p < 0.05$) between pre-and post-test measures. The shuttle training has a remarkable effect on agility, flexibility, reaction time, and vertical jump performance among basketball players. The results revealed significant improvements in both the fitness components of Basketball players. Similarly, another recent study by Verma (2011) assessed the effects of Shuttle Training on agility and flexibility in some basketball player groups. The findings demonstrated significant increases in agility and flexibility in both experimental groups postintervention, highlighting the effectiveness of these training modalities. These findings support the hypothesis, suggesting that significant differences are likely to be found in agility and flexibility among groups after the intervention, with greater improvements observed in the Shuttle Training group. The alternative hypothesis proposes that a significant difference may be found in the pre- and post-test measures of agility and flexibility within the experimental groups, Shuttle Training. This hypothesis aimed to assess the effectiveness of each training modality in eliciting improvements in physical fitness parameters over the course of the intervention period. If the alternative hypothesis is supported, indicating significant improvements in agility and flexibility from pre- to post-test within both experimental groups, it suggests that Shuttle Training interventions were effective in enhancing these physical fitness parameters.

4.1 Effect of shuttle training on basketball players

The purpose of this study was to examine the effects of shuttle training on agility, flexibility, reaction time, and performance among basketball players. The present study highlights that gross root equality is important for interpreting the effects of shuttle training on performance variables. The discussion of the present study highlights that the assumption of baseline equality is critical for interpreting the true effects of shuttle training on performance variables. Previous studies indicated that high-intensity, movement-based drills such as shuttle training can significantly improve athletic performance (Verma, 2011). This study observed improvement in agility, which can be explained by the dynamic nature of shuttle training that involves quick changes of direction and acceleration.
Movement pattern closely related to the demands of basketball, where players constantly change their position in response to the match situation. The decrease in agility time explored improved neuromuscular coordination and efficiency. Findings of this study aligned with previous research, which revealed that change of direction drills and sport-specific movement training significantly improve agility performance (Wang & Zhang, 2022). Shuttle training incorporates repeated reaching and stretching movements that can contribute to enhancing flexibility. According to Yap et al. (2017). Shuttle training and dynamic methods can improve flexibility and performance, which is beneficial in sports like basketball, where agility and injury prevention are crucial. Reaction time indicated significant improvement, which can contribute to the quick and repetitive response nature of shuttle training. These drills require athletes to respond rapidly to directional change and motor execution. These findings align with a previous study exploring that sport-specific shuttle training can improve cognitive -motor performance and decrease the response time in basketball players (Young et al. 2015).
Overall, the analysis of this study is aligned with previous literature, confirming that shuttle training is an effective and practical method for enhancing the agility, flexibility, and reaction time in basketball players. It provides an effective training approach that addresses multiple fitness components.

4.2 Research limitations

Our sample was based on the maximum effort given the available resources; however, the 30 participants are still insufficient. Based on our analysis, the achieved statistical power was (independent t-test) and (ANOVA) with an effective size. This flaw may have reduced our ability to detect effects, increased the error, and limited the generalizability of our results. Therefore, future research experiments with large sample sizes are needed to replicate our findings. The shuttle training results were measured only before and after the intervention in the intervention group. Additionally, the short intervention period and low frequency of intervention may have contributed to the data sensitivity issue. Further in-depth studies are required to explore the effects of Shuttle Training on school-level basketball players.

5. Conclusion

The findings of this study showed the significant positive effects of shuttle training on the agility, flexibility, and reaction time of basketball players. During the 8-week intervention, participants of both groups demonstrated remarkable improvements in agility and flexibility, especially more significantly as compared to reaction time. This training approach offers benefits for multiple aspects of the physical fitness of basketball players. Shuttle training enhances agility, flexibility, and reaction time essential for the demands of basketball. Training enhances agility, flexibility, and reaction time essential for the demands of Basketball. The combination of these modalities may contribute to improved performance on the Basketball court, including enhanced agility, flexibility, reaction time, and vertical jump.

These findings have dominant indications for coaches, trainers, and players who are engaged in basketball. Shuttle training programs for basketball players may help to maximize their physical fitness and enhance overall athletic performance. Furthermore, the versatility of training can help prevent monotony and fatigue associated with traditional training methods and enhance the long-term sustainability of training programs.

However, research is required to explore the impacts of different training methods on basketball players' performance. Overall, shuttle training indicates an inclusive and effective training program for basketball players to improve their agility, flexibility, and reaction time. These findings contribute to their success on the court in competitions.

5.1 **Recommendations**

1. Based on findings, it is recommended that basketball schools, coaches, and trainers are required to consider integrating Shuttle Training into the regular training programs of Basketball players.

2. It is recommended that a specific training schedule be adopted for the improvement of every aspect of the Basketball players. This specific training program can enhance the athletic performance of basketball players.

3. It is also recommended that, through specialized training schedules, the weaknesses of the Basketball players be converted into strengths.

4. Findings recommended that mixed training programs may be relied upon by the coaches and trainers for assessments and identification of areas for improvement and excellence.

5.2 Data availability statement

The raw data supporting this conclusion of this article will be made available by the authors without any reservation.

5.3 Ethics statement

Ethical approval was obtained from the relevant authorities. All participants were informed of the study's purpose, risks, and benefits. Participants were assured of the confidentiality of their data and were free to withdraw from the study at any time without consequence.

5.4 Fundings

This study is not financially supported by any special project.

5.5 Conflict of interest

The authors declare that the research was conducted in the absence of any commercial and financial relationship that could construct any potential benefits of interest.

5.6 Publisher's note

All the opinions and claims in this article belong only to the authors. They do not necessarily reflect the views of their organizations, the publisher, the editors, or the reviewers. The publisher does not guarantee or support any product mentioned in the article or any claims made by its manufacturer.

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