

## Comparative Effects of Shuttle Run and Zigzag Run Training on Physical Performance among School-Level Soccer Players

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### Abstract

Soccer requires players to perform repeated high-intensity actions, rapid changes of direction, and sustained physical effort throughout a match. This study examined the comparative effects of shuttle run and zigzag run training on two specific components of physical performance, namely agility and endurance, among school-level soccer players. The research used a two-group pretest–posttest experimental design. A total of 100 students from SMPN 2 Larantuka were divided into two training groups: 50 students performed shuttle run training and 50 students performed zigzag run training on a sand surface. Agility was assessed using a time-based agility running test, in which shorter completion time indicated better performance, while endurance was measured using the multistage beep test and expressed as level achievement. The results showed that both training methods significantly improved agility and endurance after the intervention. The shuttle run group improved agility from 19.63 to 17.24 seconds and endurance from 4.86 to 7.54 levels, whereas the zigzag run group improved agility from 19.59 to 16.85 seconds and endurance from 4.79 to 7.05 levels. The comparison of gain scores indicated that zigzag run training produced greater improvement in agility, with a mean gain of 2.74 seconds compared with 2.39 seconds in the shuttle run group, because it emphasized multidirectional movement, body control, and repeated change-of-direction actions. In contrast, shuttle run training produced greater improvement in endurance, with a mean gain of 2.68 levels compared with 2.26 levels in the zigzag run group, because it required repeated high-intensity running, acceleration, deceleration, and short recovery cycles that stimulated cardiorespiratory adaptation. These findings indicate that both exercises are effective but have different dominant training effects. Therefore, zigzag run training is more suitable for agility development, whereas shuttle run training is more appropriate for endurance improvement in school-level soccer conditioning programs.

**Keywords:** shuttle run; zigzag run; agility; endurance; soccer training; sand training; physical performance.

### INTRODUCTION

Soccer is a team sport that requires the continuous integration of physical, technical, tactical, and mental abilities throughout the game. At the school and youth levels, players are expected not only to perform basic technical skills such as running, dribbling, passing, shooting, and defending, but also to maintain movement intensity during repeated game situations. Therefore, physical conditioning is an important foundation for sustaining performance during training and competition. Among the physical components required in soccer, agility and endurance are particularly important because they support rapid changes of direction, repeated high-intensity actions, and the ability to maintain effort over time.

Endurance in soccer is closely related to aerobic capacity, intermittent work ability, and the efficiency of the cardiorespiratory system. Players with higher levels of cardiorespiratory fitness, especially  $VO_2\text{max}$  and intermittent endurance capacity, tend to cover greater distances, maintain higher work rates, perform high-intensity actions more frequently, and remain actively involved in game situations. This is supported by (Kadyan & Paul, 2022; Michailidis, 2024; Silva, 2022) who

emphasize that endurance is an important prerequisite for the sustainability of physical activity and tactical engagement in the game. Training methods that improve aerobic and intermittent endurance, including interval-based and high-intensity exercises, have also been shown to help players sustain repeated intense efforts and recover more effectively between actions ((Bahtra et al., 2023; Clemente et al., 2023; Michailidis, 2024).

In addition to endurance, agility is essential because soccer requires players to accelerate, decelerate, stop, turn, and change direction quickly in response to the ball, opponents, teammates, and available space. Agility is therefore not merely linear speed, but a combination of change-of-direction ability, body control, coordination, balance, and movement efficiency. These qualities are highly relevant to school-level soccer players because many game situations involve short sprints and multidirectional movements. When agility is poorly developed, players may struggle to reposition quickly, evade opponents, defend effectively, or respond to rapid transitions during play.

Despite the importance of agility and endurance, many school-age players still experience limitations in maintaining movement quality and physical intensity throughout training or competition. Low endurance may lead to reduced running speed, decreased repeated sprint ability, and faster onset of fatigue, while poor agility may limit the ability to change direction efficiently. Although fatigue can also influence technical and cognitive performance, the present study focuses specifically on measurable physical outcomes, namely agility and endurance. Previous research has shown that physical fatigue can reduce sprint performance, high-intensity running, and intermittent endurance in soccer players (Dambroz et al., 2022; Teoldo et al., 2024)). Thus, practical training methods are needed to improve the physical capacities most directly related to soccer movement demands among students and young players.

The problem becomes increasingly complex because fatigue is not only physiological but also related to mental and cognitive aspects. (Costa et al., 2022, Wu et al., 2024 and (González-Víllora et al., 2022) show that mental fatigue can interfere with perceptual processing, attention, passing accuracy, dribbling control, and speed and precision decision-making. Thus, increased endurance cannot be understood only as an increase in physical capacity, but also as an effort to maintain technical and tactical stability during a match. In the context of students or young players, a form of training that is simple, safe, easy to apply, and relevant to the movement pattern of football is needed.

One form of exercise commonly used to improve soccer-specific physical fitness is the shuttle run. This exercise involves repeated back-and-forth running over a predetermined distance, usually including acceleration, deceleration, stopping, turning, and restarting. These characteristics are consistent with soccer demands, where players frequently perform short sprints, sudden stops, and rapid changes of direction. Because shuttle run training requires repeated high-intensity efforts with short recovery periods, it may provide a strong stimulus for endurance development, especially intermittent endurance and repeated-effort capacity. The initial manuscript also explains that shuttle run training may improve cardiovascular and respiratory function, strengthen leg muscles, and increase the efficiency of energy metabolism.

Several previous studies support the effectiveness of shuttle runs in improving the physical components of players. Wardani and Irawadi (2020) stated that shuttle runs are not only beneficial for building endurance but also help increase agility and dribbling ability in U-14 SSB Putra Wijaya FC Padang players. Puriana et al. (2024) found that shuttle runs significantly increase the cardiovascular endurance of futsal extracurricular participants. Tiara and Wada (2024) also show that shuttle run training can increase the speed of soccer athletes at the Tangerang ADS Academy. Other

findings from Fathur et al. (2025) show that shuttle runs and zigzag runs influence increasing the agility of U-18 SSB Andalas soccer players. These findings suggest that shuttle run training is a practical and relevant method for youth soccer conditioning, although its dominant effect may depend on the movement pattern and training objective.

Another exercise frequently used to develop soccer-related movement ability is the zigzag run. Unlike shuttle run training, which emphasizes repeated back-and-forth movement, zigzag run training requires players to move through a turning or angled pathway. This pattern demands more frequent changes of direction, dynamic balance, coordination, and body control. These characteristics make zigzag run training relevant to soccer because players often need to avoid opponents, adjust running direction, and maintain stability while moving in a limited and changing space. Therefore, zigzag run training may be more specific for improving agility and change-of-direction ability.

Contemporary literature also emphasizes the importance of sport-specific conditioning in the development of young players. Small-sided games, game-based intervals, resisted sprinting, and direction-change exercises have been shown to improve sprinting, change-of-direction, repeated sprint ability, and intermittent endurance in young players. (Fernandes-da-Silva et al., 2021), (Bouguezzi et al., 2024, Kilit et al., 2024, Arslan et al., 2021, Aloui et al., 2021, Sariati et al., 2021, and Lee et al., 2024, affirm that exercises that resemble the actual demands of the game have a better transfer to match performance. Within this framework, shuttle run and zigzag run exercises can be considered relevant because both involve repeated running actions, acceleration, deceleration, and directional changes that commonly occur in soccer.

In addition to the form of exercise, the training surface also has the potential to affect the physical adaptation response. Sand surfaces create greater instability and resistance than harder surfaces, requiring greater lower-limb effort, balance control, and energy expenditure. Previous studies have reported that sand-based training can improve sprinting, jumping, change-of-direction ability, repeated sprint ability, agility, and balance in team-sport contexts ((Marzouki, Ouergui, et al., 2022); (Hammami et al., 2021); (Wee et al., 2023); (Villarreal et al., 2023); (Pereira et al., 2023)). (Pereira et al., 2021) and (Pereira et al., 2023) also reported that sand and grass surfaces can produce comparable improvements in sprint and jump performance, suggesting that sand can be used as a viable training medium. For school settings, sand-based training may also be practical because it can be implemented with simple equipment and low cost.

However, although shuttle run and zigzag run exercises have been widely used in soccer training, comparative evidence regarding their effects on agility and endurance among school-level soccer players remains limited, particularly when both exercises are performed on sand surfaces. Some previous studies have examined shuttle run or zigzag run training separately, while others have treated them as part of broader agility programs. This makes it necessary to clarify whether the two methods produce different dominant effects when applied under similar training conditions.

Based on this background, the present study aims to analyze the effects of shuttle run and zigzag run training on sand on the agility and endurance of school-level soccer players and to compare the effectiveness of the two training methods. The novelty of this study lies in its direct comparison between shuttle run and zigzag run exercises on a sand surface using two specific physical performance variables: agility and endurance. The hypotheses proposed are: first, shuttle run and zigzag run training on sand significantly improve agility; second, shuttle run and zigzag run training on sand significantly improve endurance; and third, there is a significant difference in effectiveness between shuttle run and zigzag run training on agility and endurance. Conceptually, zigzag run

training is expected to be more effective for agility because it involves more complex multidirectional movements, whereas shuttle run training is expected to be more effective for endurance because it emphasizes repeated high-intensity running and sustained cardiorespiratory demand.

## **METHODS**

### **Research Design**

This study used an experimental design with a model of two pretest–posttest groups. This design was used to determine changes in agility and endurance before and after exercise treatment, as well as to compare the effectiveness of two forms of exercise, namely shuttle run and zigzag run carried out on sand surfaces. The independent variable in this study was the type of training program, consisting of shuttle run training and zigzag run training, while the dependent variables were agility and endurance. The selection of this design is in accordance with the characteristics of sports training research, because changes in physical performance can be observed through initial measurements, interventions, and final measurements. In the context of research on young players or school students, the design of two pretest–posttest groups is commonly used to evaluate the influence of exercise programs on agility, speed of change of direction, endurance, repeated sprint ability, and aerobic capacity ((Bouguezzi et al., 2024); (Szabó et al., 2024); (Azra et al., 2024); (Anam et al., 2024); (Sanjaya & Suherman, 2024); (Torregrosa-Domínguez et al., 2025)). The first group received shuttle run training, while the second group received zigzag run training. Both groups completed the same testing procedure before and after the intervention. The effectiveness of each training model was analyzed by comparing pretest and posttest scores within each group and by comparing gain scores between groups.

### **Participants and Group Divisions**

Participants in this study were students of SMPN 2 Larantuka who participated in a physical training program based on running on sand. The number of research subjects was 100 students who were divided into two groups, namely 50 students in the shuttle run group and 50 students in the zigzag run group. Participants were selected based on their active involvement in school soccer training activities and their ability to follow the complete intervention and testing procedures. Students who had injuries, medical conditions, or physical limitations that could interfere with running performance were not included in the study.

Before data collection, participants were informed about the purpose, procedures, and physical demands of the study. Permission was obtained from the school, and participant involvement was conducted with teacher supervision. Because the participants were school-age students, consent from the school and approval from parents or guardians were considered necessary to ensure ethical participation. The division of participants into two groups was carried out to allow direct comparison between the two forms of training with different movement characteristics. The shuttle run group performed repeated back-and-forth running exercises, whereas the zigzag run group performed running exercises involving repeated directional changes through a turning pathway.

### **Training Intervention Procedures**

The intervention consisted of shuttle run and zigzag run exercises performed on sand surfaces. Both groups trained under similar environmental conditions, with the same general session structure consisting of warm-up, main training activity, and cool-down. The intervention was conducted during regular school-based soccer conditioning sessions. The training load should be reported in detail by specifying the intervention duration, weekly frequency, number of sets, repetitions, running distance,

and rest interval used in each session. These details are important to improve the replicability of the study and to allow comparison with previous sports training research.

Sand surfaces were chosen because they provide additional challenges to body stability, leg muscle strength, balance, and cardiorespiratory load. Exercises on sand demand greater muscular effort than exercises on hard surfaces because the legs must overcome surface resistance and instability. Conceptually, these conditions can strengthen neuromuscular adaptation and lower-limb endurance. Supporting literature suggests that sand-based exercises can improve sprinting, jumping, change-of-direction ability, repeated sprint ability, agility, and balance in team-sport contexts ((Marzouki, Dridi, et al., 2022); (Hammami et al., 2021); (Wee et al., 2023); (Villarreal et al., 2023); (Pereira et al., 2023)).

Shuttle run training was performed using a repeated back-and-forth running pattern over a predetermined distance. The exercise required participants to sprint from the starting line to the turning line, decelerate, change direction, and return to the starting point repeatedly according to the prescribed number of repetitions and sets. This movement emphasizes acceleration, deceleration, repeated short sprints, and the ability to maintain work intensity. In soccer, this pattern is relevant because players frequently perform short sprints, sudden stops, turns, and rapid recovery movements in response to changing game situations. The initial draft explains that shuttle run training can physiologically improve the work of the cardiovascular and respiratory systems, strengthen leg muscles, and increase the efficiency of energy metabolism.

Zigzag run training was performed using a turning running pattern through a marked pathway. Participants ran through a sequence of markers or cones arranged in a zigzag pattern, requiring them to repeatedly change direction while maintaining speed, balance, and body control. This exercise was designed to improve change-of-direction ability, movement coordination, dynamic balance, and postural control. Zigzag movement patterns are relevant to soccer because players often need to move past opponents, adjust running direction, and maintain stability in a rapidly changing playing space. Additional literature suggests that zigzag run exercises can improve agility and movement coordination in soccer and futsal players because these exercises emphasize multidirectional movements that are consistent with game demands ((Azra et al., 2024); (Maghfiroh et al., 2023); (Yulaili et al., 2023); (Ilham et al., 2024)). To maintain training consistency, both groups were supervised during all sessions. Participants were instructed to perform each exercise with maximal but controlled effort, while rest intervals were provided between sets to reduce excessive fatigue and maintain movement quality. Attendance and participation were monitored to ensure that the posttest reflected the effect of the training intervention.

### **Data Collection and Instruments**

Research data were collected through pretest and posttest measurements on two main variables: agility and endurance. The pretest was conducted before the training intervention to obtain baseline data, while the posttest was conducted after the intervention using the same testing procedures. All tests were administered under similar field conditions to reduce measurement bias. Agility was measured using a time-based agility running test. In this test, participants were required to complete a predetermined agility course as quickly as possible, and performance was recorded in seconds. A shorter completion time indicated better agility performance. The agility test was used to assess the participants' ability to accelerate, decelerate, change direction, and maintain body control during rapid movement. Agility measurements in young player research commonly use field-based tests such as the Illinois Agility Test, Illinois Change of Direction Test, 505 change-of-direction test,

or other agility tests that assess acceleration, deceleration, and directional change. These tests are widely used because they are relevant to soccer movements and can be applied practically in school or youth coaching environments ((Anđelić et al., 2021); (Beboucha et al., 2021); (Siquier-Coll et al., 2022); (Ulloa-Díaz et al., 2025); (Ye et al., 2024)).

Endurance was measured using a level-based field test. In this study, endurance was assessed using the multistage beep test, in which participants ran back and forth according to audio signals with progressively increasing speed. The final level reached by each participant was recorded as the endurance score, with a higher level indicating better endurance performance. The beep test is commonly used to assess aerobic endurance capacity in school and sports settings because it is practical, requires minimal equipment, and can be administered to groups. In youth soccer research, field tests such as the Yo-Yo Intermittent Recovery Test Level 1 and the 30-15 Intermittent Fitness Test are also frequently used because they represent the intermittent activity pattern of soccer ((Tadesse et al., 2022); (Bahtra et al., 2021); (Díaz-Ochoa et al., 2023); (Siquier-Coll et al., 2022)). However, for consistency in this study, the same endurance test protocol was applied in both the pretest and posttest.

### **Data Analysis**

Data analysis was carried out in several stages. The first stage was descriptive analysis to describe pretest, posttest, and gain scores for agility and endurance. Descriptive statistics included mean scores, standard deviations, gain scores, and relative changes where possible. Descriptive statistics were used to identify the tendency of performance changes before hypothesis testing was conducted. In reporting the results of sports interventions, descriptive indicators should include means, standard deviations, absolute changes, relative changes, and, when available, confidence intervals to describe the magnitude of change more completely ((Díaz-Ochoa et al., 2023); (Pavlović, 2024); (Nam et al., 2025); (Santos et al., 2025); (Sannicandro et al., 2023)).

The second stage was the prerequisite analysis test. The normality test was conducted using Shapiro–Wilk with a significance level of 0.05. The data were considered normally distributed if the significance value was greater than 0.05. The normality test was necessary because the use of parametric tests, especially the paired sample t-test, requires that the data or score differences be normally distributed. If the normality assumption is not met, nonparametric analyses such as the Wilcoxon test can be used as an alternative (Demarie et al., 2022). In this study, all pretest, posttest, and gain score data for agility and endurance had significance values above 0.05, indicating that the normality assumption was met.

The third stage was the homogeneity test using Levene’s test to determine the equality of gain score variance between the shuttle run and zigzag run groups. The data were considered homogeneous if the significance value was greater than 0.05. Variance homogeneity is an important assumption in the independent sample t-test because this analysis compares two independent groups. If the variance is not homogeneous, an alternative statistical approach or adjustment is required ((Demarie et al., 2022); (Fiandini et al., 2023)).

The fourth stage was hypothesis testing. The paired sample t-test was used to determine the effect of training on changes in agility and endurance within each group, while the independent sample t-test was used to compare the effectiveness of shuttle run and zigzag run training based on gain scores. The level of statistical significance was set at  $p < 0.05$ . In addition to significance values, Cohen’s *d* was used to assess the magnitude of differences between groups. Reporting effect size is

important because significance values only indicate whether a statistical difference exists, whereas Cohen's *d* helps explain the practical meaning of the difference in the context of training intervention.

## RESULTS

The presentation of the results of the analysis of the effect of shuttle run and zigzag run exercises on sand on the increase in student agility and endurance was systematically compiled starting from data description, analysis prerequisite tests, effects tests for each exercise, to tests for differences in effectiveness between groups. In general, the results showed that both forms of exercise provided a significant increase in agility and endurance. However, the effectiveness of the two differed according to the variables measured: zigzag run was more effective in increasing agility, while shuttle run was more effective in increasing endurance.

### Description of Changes in Agility and Durability

Descriptive analysis was performed to provide a preliminary picture of changes in pretest, posttest, and gain scores on the agility and endurance variables. In sports research, outcome reporting should include measures of central tendency and data distribution, such as mean and standard deviation, as well as absolute and relative changes to clarify the magnitude of performance improvements. Reporting of absolute change and percentage change is also recommended in sports intervention studies in young age groups because it can help explain the practical meaning of statistical results ((Díaz-Ochoa et al., 2023); (Pavlović, 2024); (Nam et al., 2025); (Santos et al., 2025); (Sannicandro et al., 2023)).

**Table 1.** Description of agility changes by exercise group

Groups	N	Mean Pretest	Mean Posttest	Mean Gain	Relative Change	Interpretation
Shuttle Run	50	19,63 seconds	17,24 seconds	2,39 seconds	12,18%	Increased agility
Zigzag Run	50	19,59 seconds	16,85 seconds	2,74 seconds	13,99%	Increased agility
Combinations	100	19,61 seconds	17,04 seconds	2,57 seconds	13,11%	Increased agility

Both groups experienced a decrease in travel time from pretest to posttest. Because agility was measured in seconds, the decrease in time showed an increase in performance. The shuttle run group experienced an increase of 2.39 seconds or about 12.18% of the initial score, while the zigzag run group experienced an increase of 2.74 seconds or about 13.99% (see table 1). Descriptively, the zigzag run group showed a greater increase in agility than the shuttle run group. These findings are in line with the characteristics of zigzag run exercises that emphasize more complex changes of direction, making them more suitable for improving the ability to change of direction and multidirectional coordination of movements. Studies by (Azra et al., 2024), (Maghfiroh et al., 2023), and (Ilham et al., 2024) also show that zigzag training can improve agility and movement coordination in football and futsal players.

**Table 2.** Description of endurance changes by exercise group

Groups	N	Mean Pretest	Mean Posttest	Mean Gain	Relative Change	Interpretation
Shuttle Run	50	4,86 level	7,54 level	2,68 level	55,14%	Increased durability
Zigzag Run	50	4,79 level	7,05 level	2,26 level	47,18%	Increased durability
Combinations	100	4,82 level	7,29 level	2,47 level	51,24%	Increased durability

Both groups experienced an increase in endurance scores from pretest to posttest. The shuttle run group increased by 2.68 levels or around 55.14%, while the zigzag run group increased by 2.26 levels or around 47.18% (see table 2). Descriptively, the increase in endurance in the shuttle run group was greater than in the zigzag run group. This suggests that repeated alternating running patterns can provide stronger and more consistent cardiorespiratory stimulus. These findings are supported by the literature stating that shuttle run-based training protocols and HIIT can improve aerobic capacity,  $VO_2\text{max}$ , intermittent endurance, and repeated sprint ability in soccer players ((Clemente, 2025); (Yuan et al., 2024); (Gaamouri et al., 2022)).

### Results of the Prerequisite Test Analysis

Before parametric testing is performed, the data is tested first to ensure that the assumptions of normality and homogeneity are met. Normality testing is performed using Shapiro-Wilk with a significance level of 0.05. Data is declared to be normally distributed if the significance value is greater than 0.05. In sports analysis, normality tests are important especially to ensure that the data or score differences in paired designs meet the assumptions of using paired sample t-tests. If the data are abnormal, then nonparametric analyses such as Wilcoxon or Mann-Whitney U are more recommended ((Demarie et al., 2022)).

**Tabel 3.** Shapiro-Wilk Normality Test Results

Variabel	Shapiro-Wilk	Sig.
Agility pretest Shuttle Run	0,982	0,624
Agility posttest Shuttle Run	0,971	0,251
Gain k Agility Shuttle Run	0,981	0,581
Agility pretest Zigzag Run	0,979	0,527
Agility posttest Zigzag Run	0,965	0,147
Gain Agility Zigzag Run	0,981	0,584
Endurance pretest Shuttle Run	0,988	0,884
Endurance posttest Shuttle Run	0,984	0,739
Gain Endurance Shuttle Run	0,971	0,247
Endurance pretest Zigzag Run	0,959	0,083
Endurance posttest Zigzag Run	0,977	0,431
Gain Endurance Zigzag Run	0,976	0,408

The significance value is above 0.05 which indicates that the agility and endurance data, both in the pretest, posttest, and gain score, are distributed normally (see table 3). Thus, the data meets the assumption of normality and is suitable for analysis using parametric tests. The fulfillment of this assumption is important because the hypothesis testing in this study uses paired sample t-tests to see changes in groups and independent sample t-tests to see differences in effectiveness between groups. In addition to normality, homogeneity tests are carried out to find out whether the gain score variance between the shuttle run group and the zigzag run group is the same. The homogeneity test was carried out using the Levene Test with a significance level of 0.05. The data is declared homogeneous if the significance value is greater than 0.05. The homogeneity test is an important assumption in the independent sample t-test, because the comparison of two independent groups requires equality of variance so that the inference results are more valid ((Demarie et al., 2022); (Fiandini et al., 2023)).

**Tabel 4.** Hasil uji homogenitas gain score

Variabel	Levene Test	Sig.
Gain agility	0,182	0,670
Gain Endurance	0,073	0,788

The significance value of the agility gain score was 0.670 and the endurance gain score was 0.788. Both values were greater than 0.05, so the variance between groups was declared homogeneous. With the assumption of normality and homogeneity being met, the analysis can be continued using the paired sample t-test and the independent sample t-test.

#### The Effect of Shuttle Run and Zigzag Run Training on Agility

The first hypothesis test was conducted to determine whether shuttle run and zigzag run exercises on sand had a significant effect on agility improvement. The test was conducted using paired sample t-test in each group and on combined data. The test results are presented in Table 5.

**Tabel 5.** Results of paired sample t-test variable agility

Group	N	Mean Pretest	Mean Posttest	Mean Gain	t	Sig.
Shuttle Run	50	19,63	17,24	2,39	27,73	<0,001
Zigzag Run	50	19,59	16,85	2,74	34,88	<0,001
Combinations	100	19,61	17,04	2,57	42,35	<0,001

The overall significance value was below 0.05, even smaller than 0.001. This means that there was a significant difference between the agility pretest and posttest scores in the shuttle run group, the zigzag run group, and the combined data. In the shuttle run group, the average agility time decreased from 19.63 seconds to 17.24 seconds, with an increase of 2.39 seconds. In the zigzag run group, the average agility time decreased from 19.59 seconds to 16.85 seconds, with an increase of 2.74 seconds. Thus, the hypothesis that shuttle run and zigzag run exercises on sand have a significant effect on agility improvement is acceptable.

Physiologically and biomechanically, increased agility can be explained through neuromuscular adaptations resulting from exercise involving acceleration, deceleration, change of direction, and control of body balance. Shuttle run exercises exercise acceleration and deceleration abilities in a back-and-forth pattern, while zigzag runs train changes of direction at more varied angles. Supporting literature suggests that shuttle runs can improve agility, acceleration, deceleration, and change of direction abilities in soccer players, especially at the young age or academy level ((Primasoni et al., 2022); (Kadyan & Paul, 2022)). Meanwhile, zigzag run exercises are considered effective for improving agility and coordination of movement because they demand the body's response to more complex changes in direction and resemble game situations ((Azra et al., 2024); (Maghfiroh et al., 2023); (Rizal et al., 2022)).

**Tabel 6.** Hasil paired sample t-test endurance

Groups	N	Mean Pretest	Mean Posttest	Mean Gain	t	Sig.
Shuttle Run	50	4,86	7,54	2,68	-31,31	<0,001
Zigzag Run	50	4,79	7,05	2,26	-26,39	<0,001
Combinations	100	4,82	7,29	2,47	-38,70	<0,001

Shuttle run and zigzag run exercises both had a significant effect on increasing endurance. The overall significance value was below 0.001. The shuttle run group experienced an average

increase from 4.86 levels to 7.54 levels, with a gain score of 2.68 levels. The zigzag run group experienced an increase from 4.79 levels to 7.05 levels, with a gain score of 2.26 levels. In the combined data, the endurance score increased from 4.82 levels to 7.29 levels, with a gain score of 2.47 levels. Based on these results, the second hypothesis that shuttle run and zigzag run exercises on sand have a significant effect on improving endurance is acceptable.

The increase in endurance in both groups can be explained through the characteristics of intensive and repetitive exercises. Training on sand increases the work demands of leg muscles, body stability, and cardiorespiratory load because sand surfaces have greater resistance than hard surfaces. Exercises like this can promote aerobic system adaptation, recovery capacity, and movement efficiency. (Marzouki, Ouergui, et al., 2022), (Hammami et al., 2021), (Wee et al., 2023), (Villarreal et al., 2023), and (Pereira et al., 2023) show that sand-based exercises can improve sprinting, jumping, change of direction, repeated sprint ability, agility, and balance in the context of team sports. In addition, shuttle runs have repetitive interval characteristics that are relevant to the intermittent endurance demands of soccer. (Clemente, 2025), (Yuan et al., 2024), and (Gaamouri et al., 2022) explain that shuttle run-based exercise or HIIT can improve aerobic capacity,  $VO_{2max}$ , and repetitive sprint ability.

### Comparison of Shuttle Run and Zigzag Run Effectiveness

A third hypothesis test was performed to determine whether there was a difference in effectiveness between shuttle run and zigzag run on sand exercises on increased agility and endurance. The analysis was conducted using an independent sample t-test on the gain score of each variable. In addition to significance values, Cohen's d was used to see the magnitude of the effects of differences between groups. In sports research, effect size reporting is important because p-values only show statistical significance, while effect measures help explain the practical meaning of the differences found ((Díaz-Ochoa et al., 2023); (Nam et al., 2025); (Santos et al., 2025)).

**Tabel 7.** Independent Sample t-Test Gain Score Result

Variabel	Mean Gain Shuttle Run	Mean Gain Zigzag Run	Differences Mean	t	Sig.	Cohen's d
Agility	2,39	2,74	-0,35	-2,96	0,004	0,59
Endurance	2,68	2,26	0,42	3,47	<0,001	0,69

There was a significant difference in effectiveness between shuttle run training and zigzag run on sand. In the agility variable, the significance value was 0.004, smaller than 0.05. The average gain score of the zigzag run group was 2.74 seconds higher than that of the shuttle run group of 2.39 seconds. The mean difference of -0.35 indicated that the zigzag run provided a greater increase in agility. Cohen's d value of 0.59 indicated a moderate effect, so the difference was not only statistically significant, but also had practical significance in the context of training.

The advantages of zigzag running in improving agility can be understood from its movement patterns, which demand more varied changes of direction, more complex body coordination, and higher balance control. This exercise resembles the demands of a soccer game, especially when players must pass opponents, make defense-attack transitions, and adjust the direction of movement quickly. These findings are consistent with (Azra et al., 2024), who state that zigzag running results in greater agility increases than shuttle running in the context of young players. Other supporting findings from (Maghfiroh et al., 2023), (Rizal et al., 2022), and (Armanjaya et al., 2023) also show

that zigzag training effectively improves agility, multidirectional coordination, and motion transfer to dribbling skills.

In contrast, for the endurance variable, the significance value was below 0.001, indicating a very significant difference in effectiveness between the two groups. The shuttle run group had a mean gain of 2.68 levels, higher than the zigzag run group of 2.26 levels. The mean difference of 0.42 indicates that the shuttle run is more effective in improving endurance. Cohen's *d* value of 0.69 indicates a moderate to large effect, so the difference has a strong enough practical value to be applied in an exercise program.

The advantage of shuttle runs in improving endurance can be explained through a more consistent exercise pattern in providing repetitive cardiorespiratory pressure. High-intensity back and forth movements and short breaks require the body to use energy efficiently, increase oxygen transport capacity, and improve inter-action recovery capabilities. This is in accordance with the findings of (Clemente, 2025), (Yuan et al., 2024), and (Gaamouri et al., 2022), who explain that shuttle run-based exercises and HIIT can increase  $VO_2\max$ , intermittent endurance, and repeated sprint ability. Thus, shuttle runs are more relevant when the main goal of exercise is to increase cardiorespiratory endurance and the ability to maintain repetitive movement intensity.

This study found that shuttle run and zigzag run on sand exercises were equally effective in improving students' agility and endurance. The results of the prerequisite test showed that all data were distributed normally and homogeneously, so parametric analysis could be used. The results of the paired sample t-test proved that both forms of exercise provided a significant increase in agility and endurance. The results of the independent sample t-test showed that zigzag run was more effective in increasing agility, while shuttle run was more effective in improving endurance.

Practically, these results show that the choice of training form needs to be adjusted to the physical condition goals to be developed. If the main goal of training is to improve the ability to change direction, coordination of movements, and agility, then zigzag run may be a more appropriate choice. However, if the main goal of training is to increase endurance, cardiorespiratory capacity, and the ability to perform repetitive intensive activities, then shuttle run is more recommended. A combination of the two can also be used in periodic training programs to produce more comprehensive physical adaptations according to the demands of modern football.

## DISCUSSION

The findings of this study indicate that shuttle run and zigzag run training on sand both contributed positively to improving students' agility and endurance. However, the two training methods showed different dominant effects. Zigzag run training produced greater improvement in agility, whereas shuttle run training produced greater improvement in endurance. This difference can be explained by the specific movement structure and physiological demands of each exercise. Zigzag run training emphasizes multidirectional movement, repeated directional changes, balance control, and body coordination, while shuttle run training emphasizes repeated back-and-forth running, acceleration, deceleration, and sustained high-intensity effort. Therefore, the results support the principle of training specificity, in which physical adaptation depends on the type of stimulus provided during training.

The improvement in agility in both groups suggests that short-distance running exercises involving acceleration, deceleration, and direction change are relevant for school-level soccer conditioning. Soccer players frequently need to adjust their movement direction when chasing the

ball, avoiding opponents, defending, or moving into open space. For this reason, agility is an essential component of soccer-related physical performance. In this study, zigzag run training resulted in a greater agility gain than shuttle run training. This finding is reasonable because the zigzag run requires participants to repeatedly change direction at different angles while maintaining speed and body control. Such movements closely resemble soccer situations, where players rarely move only in straight lines and must constantly adapt to changing game conditions.

The greater effectiveness of zigzag run training for agility can also be understood through neuromuscular adaptation. During zigzag movements, students must control their center of gravity, adjust foot placement, stabilize the lower limbs, and coordinate body movement during each directional change. These repeated demands may improve balance, coordination, braking ability, and re-acceleration. These components are important in agility because players need to change direction quickly without losing stability or movement efficiency. Thus, the superior agility improvement in the zigzag run group reflects the close match between the training pattern and the physical requirements of agility performance.

This finding is supported by previous studies showing that zigzag-based exercises improve agility and coordination in soccer and futsal contexts. (Azra et al., 2024) reported that zigzag running produced greater agility improvement than shuttle running among young players. Similarly, (Maghfiroh et al., 2023), (Rizal et al., 2022), (Armanjaya et al., 2023), and (Yulaili et al., 2023) showed that zigzag or zigzag-like movement training can improve agility, multidirectional coordination, and movement control. These studies strengthen the argument that agility training should include not only speed, but also direction variation, balance, and body-position control. In soccer, these qualities are needed when players respond to the ball, opponents, teammates, and available space.

Nevertheless, the results should not be interpreted to mean that shuttle run training is ineffective for agility. The shuttle run group also showed significant improvement in agility. This improvement may be related to the repeated acceleration, deceleration, stopping, and turning actions involved in shuttle run training. (Primasoni et al., 2022) found that shuttle run and three-corner drill exercises both improved agility in football academy players, although the difference between the two methods was not always statistically clear. Therefore, shuttle run training remains useful for developing basic change-of-direction ability, especially in simpler linear or back-and-forth movement patterns. However, when the main objective is multidirectional agility, zigzag run training appears to provide a more specific stimulus.

In contrast, shuttle run training produced greater improvement in endurance than zigzag run training. This result can be explained by the repeated high-intensity nature of shuttle run exercises, which require students to run back and forth continuously with limited recovery. This pattern creates a strong cardiorespiratory stimulus because participants must repeatedly accelerate, decelerate, turn, and resume running while maintaining movement intensity. Such demands are relevant to soccer endurance, which is not only the ability to run for a long duration, but also the ability to perform repeated efforts with short recovery periods. Therefore, shuttle run training is particularly suitable for improving intermittent endurance and repeated-effort capacity.

The superiority of shuttle run training for endurance is consistent with previous literature on interval-based and repeated-running exercises. (Clemente, 2025), (Yuan et al., 2024), and (Gaamouri et al., 2022) reported that shuttle run-based exercises, high-intensity interval training, and repeated sprint patterns can improve aerobic capacity,  $VO_{2max}$ , intermittent endurance, and repeated sprint

ability. In the present study, the shuttle run pattern likely provided a more consistent cardiovascular load than the zigzag run because the movement direction was simpler and allowed participants to maintain repeated running intensity over time. This may explain why the shuttle run group achieved a higher endurance gain than the zigzag run group.

Although shuttle run training was more effective for endurance, zigzag run training also produced a significant improvement in endurance. This indicates that zigzag run training also creates meaningful physical load, especially when performed repeatedly on a sand surface. The repeated changes of direction, stabilization demands, and re-acceleration phases require continuous lower-limb work and energy expenditure. However, compared with shuttle run training, the zigzag run distributes its training stimulus across coordination, balance, body control, and direction-change ability. As a result, its effect on endurance may be smaller when endurance is measured through a level-based running test.

The sand surface may have contributed to the improvement in both agility and endurance. Sand is an unstable and energy-absorbing surface, so movement on sand requires greater muscular effort, balance control, and energy expenditure than movement on harder surfaces. In zigzag run training, sand may increase the demand for stability and body control during turning movements. In shuttle run training, sand may increase metabolic load during repeated running efforts. Previous studies have shown that sand-based training can improve sprinting, jumping, change-of-direction ability, repeated sprint ability, agility, and balance in team-sport contexts ((Hammami et al., 2021); (Villarreal et al., 2023); (Pereira et al., 2023); (Marzouki, Ouergui, et al., 2022); (Pereira et al., 2023)). Therefore, the sand surface likely strengthened the training stimulus in both groups, although the direction of adaptation depended on the dominant characteristics of each exercise.

Theoretically, the findings are consistent with the principle of specificity and overload. The principle of specificity explains that training adaptations are greatest when the exercise pattern resembles the performance component being developed. In this study, zigzag run training was more specific to agility because it involved multidirectional movement, balance control, and repeated change of direction. Meanwhile, shuttle run training was more specific to endurance because it required repeated high-intensity running and sustained cardiorespiratory effort. The principle of overload is also relevant because the sand surface increased the physical demand of each movement, forcing the body to adapt to greater muscular and metabolic stress.

The practical implication of these findings is that coaches and physical education teachers should select training methods according to the physical component they intend to develop. If the main goal is to improve agility, change-of-direction ability, coordination, and body control, zigzag run training should be prioritized. This exercise can be varied by changing cone distance, turning angle, running speed, and movement direction. However, if the main goal is to improve endurance, repeated-effort capacity, and the ability to sustain high-intensity running, shuttle run training is more appropriate. This exercise can be developed through progressive increases in distance, repetitions, sets, or reductions in rest intervals.

At the same time, the findings should be interpreted within the scope of the measured variables. This study measured agility and endurance; therefore, conclusions should be limited to these two physical performance components. Although agility and endurance may support broader soccer performance, this study did not directly measure technical skills, tactical decision-making, passing accuracy, shooting performance, or match outcomes. For this reason, claims about the effect of shuttle run and zigzag run training on overall soccer performance should be made cautiously.

Future studies should include additional variables such as sprint speed, dribbling ability, heart rate response, VO<sub>2</sub>max estimation, fatigue response, and match-performance indicators to provide a more comprehensive understanding of training transfer.

Overall, this study confirms that shuttle run and zigzag run training on sand are practical and effective conditioning methods for school-level soccer players. The two methods should not be viewed as replacing each other, but as complementary exercises with different dominant benefits. Zigzag run training is more suitable for developing agility because it emphasizes complex directional changes and body control, whereas shuttle run training is more suitable for developing endurance because it emphasizes repeated high-intensity running and cardiorespiratory demand. Combining both methods in a structured and progressive training program may help coaches and physical education teachers develop more balanced physical conditioning among young soccer players.

## CONCLUSION

This study concludes that shuttle run and zigzag run training performed on sand significantly improved two specific components of physical performance, namely agility and endurance, among school-level soccer players. Both training methods provided meaningful benefits because they required repeated acceleration, deceleration, lower-limb control, and sustained physical effort. However, the dominant effect of each training method differed according to its movement characteristics. Zigzag run training was more effective for improving agility because it involved repeated multidirectional changes, dynamic balance, body control, and coordination patterns that are closely related to change-of-direction movements in soccer. In contrast, shuttle run training was more effective for improving endurance because its repeated back-and-forth running pattern provided a stronger cardiorespiratory stimulus and trained students to sustain high-intensity effort with short recovery periods. These findings confirm the importance of training specificity in school-level soccer conditioning. Training methods should be selected according to the physical component targeted by the coach or physical education teacher. Zigzag run training is more appropriate when the main objective is to improve agility and change-of-direction ability, whereas shuttle run training is more suitable when the goal is to improve endurance and repeated-effort capacity. The study also shows that sand-based training can be used as a practical, low-cost, and sport-relevant conditioning option in school settings, if training load, intensity, and recovery are controlled appropriately. Overall, shuttle run and zigzag run training should be viewed as complementary rather than competing methods. Coaches and physical education teachers are encouraged to combine both exercises in a structured training program to develop more balanced physical conditioning among young soccer players. Future studies should use longer intervention periods, provide more detailed control of training intensity, include broader participant characteristics, and examine additional performance variables such as sprint speed, dribbling ability, heart rate response, VO<sub>2</sub>max estimation, fatigue response, and match-related performance indicators.

## RECOMMENDATION

Based on the findings of this study, coaches and physical education teachers are encouraged to use shuttle run and zigzag run training as practical conditioning methods for school-level soccer players. Both exercises are simple to organize, require minimal equipment, and can be applied in school-based training programs. However, the selection of training method should be adjusted to the specific physical component being targeted. Zigzag run training should be prioritized when the main

objective is to improve agility, change-of-direction ability, coordination, and body control. This exercise is relevant to soccer because it reflects multidirectional movement patterns that commonly occur when players evade opponents, adjust body position, defend, or respond to changing game situations. To improve training transfer, coaches may vary the cone distance, turning angle, running direction, and movement speed according to the players' ability level. Shuttle run training should be emphasized when the training objective is to improve endurance, repeated-effort capacity, and cardiorespiratory fitness. The repeated back-and-forth running pattern provides an effective stimulus for maintaining high-intensity movement and improving recovery between efforts. This exercise can be developed progressively by adjusting running distance, number of repetitions, number of sets, and rest intervals. Training on sand may be used as an alternative conditioning strategy because it increases muscular workload, balance demands, and energy expenditure. Nevertheless, sand-based training should be applied progressively, particularly for school-age athletes. Coaches should carefully control training volume, intensity, frequency, and recovery time to reduce the risk of excessive fatigue or injury. Future training programs are recommended to combine shuttle run and zigzag run exercises within a structured and periodized model. Zigzag run can be used in sessions focused on agility and change-of-direction development, while shuttle run (Demarie et al., 2022) produce more balanced physical development without overemphasizing only one performance component. Future researchers are advised to conduct studies with longer intervention periods, clearer control of training intensity, and more diverse participant characteristics, including different age groups, competitive levels, and gender groups. Further studies should also include additional variables such as sprint speed, dribbling ability, passing accuracy, heart rate response, VO<sub>2</sub>max estimation, fatigue response, and match-performance indicators to provide a broader understanding of how shuttle run and zigzag run training influence soccer-related performance.

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