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EFFECT OF COMPLEX TRAINING ON SPEED, CHANGE OF DIRECTION AND EXPLOSIVE POWER IN U-15 AND U-18 SOCCER PLAYERS

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CONFIRMATION BY PANEL OF EXAMINERS

I certify that a Panel of Examiners has met on 27th January 2026 to conduct the final examination of on his thesis entitled “Effect of Complex Training on Speed, Change of Direction and Explosive Power in U-15 and U-18 Soccer Players” in accordance with Universiti Teknologi MARA Act 1976 (Akta 173). The Panel of Examiner recommends that the student be awarded the relevant degree. The Panel of Examiners was as follows:

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I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

Modern soccer is a fast-paced, high-intensity sport involving frequent sprints, jumps, changes of direction (COD), and explosive movements. Players perform over 1,200 activity variations per match, emphasizing the importance of speed, agility, and power. Growth and biological maturation, particularly during adolescence, play a key role in athletic development, with changes in muscle-tendon structure and elevated androgen levels influencing performance. Maturation was not assessed; age-group comparisons were by U-15/U-18. The puberty period is critical for skill acquisition, making appropriate training essential for maximizing performance and minimizing injury. This study examines the impact of age and complex training (CT) on speed, COD, and power in youth soccer players. Secondary school players were categorized into under-15 (U-15) and under-18 (U-18) groups across three studies. Study 1 found significant differences in explosive power between age groups ($p=0.04$), with speed approaching significance ($p=0.05$), while COD showed no significant differences. Study 2 assessed an 8-week CT program, revealing significant improvements across all measures, though no significant differences between groups. Study 3 compared a CT group to a control group, showing significant within-group improvements, but no significant differences between groups except in COD (Right). These findings highlight the benefits of CT in enhancing soccer-specific physical attributes and provide insights for optimizing performance training in youth athletes.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

On the recent years, modern soccer has experienced a significant evolution, transforming into a fast-paced intermittent sport (Michailidis et al., 2021; Yu et al., 2021; Andrašić et al., 2021) which consisted of short-duration and high intensity activities such as sprinting, running, jumping, dueling, tackling, changing direction and various instances of walking and standing (Pavillon et al., 2021; Gualtieri et al., 2023). In a typical soccer game, players engaged in high-intensity movements every 60 seconds and maximal efforts every 4 minutes and during the whole match (Pavillon et al., 2021). It has been reported that players execute over 1,200 unpredictable variations in activity, which includes about 11-12% of sprinting within the total distance covered, along with 1,200-1,400 directional changes, 30-40 instances of jumping and tackling and between 90 to 140 interactions with the ball which include passing, kicking, and dribbling (Yu et al., 2021; Negra et al., 2022; Hulton et al., 2022) which most of the actions are mostly highly explosive (Križaj, 2020).

By having great physiological abilities may benefits in optimizing performance and could enhance tactical implication of the coaches (Zghal et al., 2019; Yu et al., 2021; Keiner et al., 2021). The significance of having superior speed, agility in changing direction, and explosive power are not only important for individual players but also, these physical capabilities may affect the team's performance not only in adult but also in youth soccer game (Zghal et al., 2019; Andrašić et al., 2021). Attackers rely on these abilities to apply pressure and execute tackles to gain goal scoring opportunities, while defenders use them to close down opponents' space and limit attacking opportunities, thus minimizing threats to the team which may lead to concede goals (Andrašić et al., 2021). This trend emphasizes how modern soccer has become highly athletic which physical abilities such as strength, power, sprinting, jumping, and changing direction play crucial roles in determining success in invasive sport like soccer (Sonesson et al., 2020; Sariati et al., 2020; Keiner et al., 2021). This is supported by Križaj (2020) where in the study indicated that there were moderate to strong relationship on how sprinting and changing direction required adequate amount of lower limb explosive power.

Speed is one of the key performance indicator to success in soccer which defined as the ability to run at high velocity and cover a distance from one point to another as fast as possible (Yildiz et al., 2018). In practical terms, it refers to the body's capacity to move swiftly and cover ground as quickly as possible (Krosta et al., 2020). Speed is essential throughout both halves of a soccer game (Field et al., 2022). In game situations, players typically cover between 110-330 meters of sprinting or high-speed running, depending on their position (Yildiz et al., 2018; Krosta et al., 2020). Saeidi and Khodamoradi (2017) note that professional players cover 5–10% less distance in the second half, especially at medium (11.1–19.0 km/h) and high (18.0–30.0 km/h) intensities. However, Reinhardt et al. (2019) found that elite soccer players cover 24%-36% of their total distance at high-intensity running and 36%-63% during linear sprints throughout the game. For youth soccer players, it has been reported that they cover approximately 6 to 8 kilometers per match and accomplish an average of 80 accelerations (>1 m·s−2), with each lasting up to 2 to 4 seconds (Fernández-Galván et al., 2022). Sprint performance in youth players is closely linked to lower body muscle strength and power, with players who possess strong sprinting abilities often having a greater advantage in goal scoring opportunity (Sonesson et al., 2020).

Over the past few decades, reactive agility and change of direction (COD) were often considered synonymous (Andrašić et al., 2021). However, ongoing research has distinguished COD as a movement where no immediate reaction to a stimulus is required, meaning the direction change is pre-planned or deliberate (Andrašić et al., 2021). COD, a key component of speed that involved rapid, whole-body movements that include phases of acceleration, deceleration, and re-acceleration in a different direction, which relevant in typical soccer game (Falch et al., 2019). COD is vital in invasive sports like soccer, where players frequently need to change direction (Sariati et al., 2020; Michailidis et al., 2021). CODs in soccer are determined by the rate of stride adjustment, sprint pace, and characteristics of leg muscles such as strength, power, and reactive strength (Horníková and Zemková, 2021). A soccer player usually change direction every 2–4 seconds during a match, resulting up to 1,200–1,400 changes in total during a match Keiner et al., 2021. This frequency defines the importance of COD for efficient movement during soccer play. Players with higher COD capabilities are better equipped to gain an advantage on the field (Keiner et al., 2021). Trecroci et al., (2020) further underline that COD skills such as side-steps, swerves, turns, and crossover steps are essential for evading opponents, creating space, and positioning may lead to higher scoring opportunities.

Explosive power is the ability to produce strength and speed in muscle contractions, resulting in fast and forceful movements (Darni & Elkadiowanda, 2019). Power plays a crucial role in many invasive sports, including soccer (Joksimović et al., 2019). This component relies on a combination of muscular strength and the speed of movement, during movements execution (Darni & Elkadiowanda, 2019). In soccer, lower limb explosive power is important which it influence speed and the ability to change direction. Besides that, player who had appropriate lower limbs explosive power could enhance their jumping, turning, and sprinting capabilities which thn may influence and improving overall performance (Franca et al., 2021; Cossio-Bolaños et al., 2021). This is supported by Joksimović et al. (2019) highlight that explosive power is vital for executing high-speed actions such as sprinting and jumping. In soccer, power is crucial for explosive muscle contractions also play crucial role during movements like shooting, making passes, jumping for headers, and quickly changing direction in one-on-one duels (Behm, 2018) which then may influence the team's advantages during the game. Jusoh et al. (2019) emphasize that power is one of the most important physical factors for success in modern soccer, with power (strength-speed), speed, and related components being essential for a team's performance.

When working with young athletes, it's crucial to consider their long-term development, which makes managing training loads and associated fatigue even more important (Magallanes et al., 2022). While the precise physiological and molecular mechanisms behind training adaptations are still being researched, there is clear evidence that to maximize a young player's performance potential across adolescence and into late adolescence, specific and appropriate training program must be implemented to gradually increase athletes' physical capabilities (Trecroci et al., 2020; Magallanes et al., 2022). Therefore, when designing and implementing training programs for young athletes, it's essential to ensure that the program is not only effective in improving performance but also efficient while avoiding any physical harm or injuries.

One of the method to improve all the three components is complex training (CT) (Greenwood and Carter, 2014; Wang et al., 2023). CT could be used to fulfill the requirements for soccer players and it is stated that it suitable to be used to improve muscular strength, explosive power and its' demands (Talpey et al., 2016; Wang et al., 2023). CT is a training which combining both resistance training (RT) and plyometric training (PT) in the same training session (Greenwood and Carter, 2014; Wang et al., 2023). This training regime is supported by the assumption of post-activation potential (PAP) of the neuromuscular system which it helps in increasing the muscle contraction related to its' previous contraction (Cavaco et al., 2014; Wang et al., 2023). The procedure of CT is by performing maximal or high-intensity dynamic exercises followed by light exercises similar to biomechanical exercise patterns (Greenwood and Carter, 2014; Lim and Barley, 2016; Wang et al., 2023). Past studies have shown that CT not only could improve individual but also team performance of athletes which significant effects have been shown towards improvement of motor unit recruitment and stored energy in the muscle tendon unit during the shortening phase of the stretch shortening cycle (SSC). This may cause the improvement of muscle capabilities to produce greater explosive power during movement execution after the maximum or near maximum contraction during the CT training (Freitas et al., 2017) which these characteristics may help by giving advantages towards the athletes to success in their sport.

Despite the well-documented importance of speed, change of direction (COD), and explosive power in soccer performance, there is limited research on how these physical attributes differ across different chronological age groups (U-15 vs. U-18) and how they respond to the same structured training program (Rodriguez-Rosell et al., 2017; Giudicelli et al., 2021). The rationale for selecting these age groups stems from a scarcity of research that explores changes in physical performance among different chronological age groups; biological maturation may vary within and between these groups, but it was not assessed in the present thesis (Giudicelli et al., 2021; Fernández-Galván et al., 2022) which this current study highlighting chronological age that cause the athletes' performance differences where typically chronological age served as the primary grouping variable in youth sport research; however, chronological age does not directly measure biological maturation, and maturation was not assessed in this thesis. (Ke et al., 2021). Additionally, while Complex Training (CT) has been shown to improve athletic performance, its effects on youth soccer players remain insufficiently explored (Ke et al., 2021; Wang et al., 2023). Differences by stage of biological maturation have been proposed, but maturation was not assessed in this thesis and is discussed here as theoretical background only. Existing literature suggests that biological maturation may be associated with differences in physical performance during adolescence; however because maturation was not measured in the present thesis, maturational mechanisms are presented as theoretical context rather than tested explanations. Moreover, pass studies indicate that youth athletic performance may plateau after age 15, but the relationship between age, training response, and performance progression is still unclear (Soneeson et al., 2020).

To address these gaps, this thesis consist of three interrelated studies; where Study 1 investigated how U-15 and U-18 soccer players differ in speed, COD, and explosive power before any intervention. It fills the research gap by establishing baseline performance differences between the U-15 and U-18 chronological age groups, providing insight into age-group differences prior to any intervention. While Study 2 examined how an 8-week CT program effects speed, COD, and explosive power in both age groups. This part addresses the gap by determining whether younger and older players respond differently to the same CT program, thus clarifying whether age-related performance gaps can be reduced through training. Last but not least, Study 3 compares the effect of CT against a control group to evaluate the true effectiveness of CT in enhancing soccer performance. This fills the gap by verifying whether CT provides significant improvements beyond normal soccer training and whether the gains differ based on age and maturity.

By integrating these three studies, this research aims to clarify chronological age-related performance differences and evaluate the effectiveness of CT in youth soccer development.

1.2 Problem Statement

Despite the recognized importance of speed, change of direction and explosive power in modern soccer, several research gaps remain. First, limited studies have compared physical performance differences between youth soccer players of different chronological age groups, particularly U-15 and U-18 players (Rodriguez-Rosell et al., 2017). While older players are generally assumed to demonstrate superior performance due to maturation, empirical evidence confirming these differences remains limited.

Second, there is insufficient research examining how different age groups respond to the same structured training intervention (Zghal et al., 2019). Most CT studies have focused on adult athletes, with fewer investigations involving youth populations Peitz et al., (2018). Additionally, the reason for selecting these age groups stems from a scarcity of research that explores changes in physical performance among different chronological age groups(Giudicelli et al., 2021; Fernández-Galván et al., 2022). Although complex training has been reported to enhance strength and power in various sports, there is limited evidence verifying its effectiveness in improving speed, COD and explosive power among youth soccer players compared to normal training routines (Abdelkader et al., 2016 ; Freitas et al., 2017).

1.3 Purpose of Study

The purpose of this thesis is to examine the effects of complex training (CT) on speed, change of direction (COD), and explosive power in U-15 and U-18 soccer players through three interrelated studies.

1. To examine the influence of chronological age on speed, COD, and explosive power.
2. To determine the effects of an 8-week CT program on these performance variables across age groups.
3. To evaluate the effectiveness of CT compared to a control group.

1.4 Research Objectives

a) To examine the effects of chronological age on speed, change of direction and explosive power for U-15 and U-18 soccer players (Chapter 3 – Study 1).

b) To investigate the difference between U-15 and U-18 soccer players in speed, change of direction and power performance after underwent 8 weeks of Complex Training program (Chapter 4 – Study 2).

c) To investigate the differences between the Complex Training program groups and control group in speed, change of direction and power performance after 8 weeks of intervention (Chapter 5 – Study 3).

1.5 Research Question

a) Are there any effects of chronological age on speed, change of direction and explosive power between U-15 and U-18 soccer players (Chapter 3 – Study 1).

b) Is there any differences between U-15 and U-18 soccer players in speed, change of direction and power performance after underwent 8 weeks of Complex Training program (Chapter 4 – Study 2).

c) Is there any differences between the Complex Training program groups and control group in speed, change of direction and power performance after 8 weeks of intervention (Chapter 5 – Study 3).

1.6 Significance of Study

1.6.1 Athletes

The results of this study could benefit athletes involved in soccer, particularly those requiring specific strength and conditioning programs to enhance their speed, change of direction (COD) and power-related performance. By implementing the findings from this study, athletes may improve key physical attributes necessary for high-performance soccer play.

1.6.2 Coaches, Trainers and Organization/Governing Bodies

This study provided valuable insights for coaches and trainers by offering important information about complex training (CT) programs. Coaches and trainers could use this information to design more effective training programs that incorporate CT, aimed at improving the overall performance of their athletes. Organizations such as Majlis Sukan Negara (MSN), Football Association of Malaysia (FAM) and Akademi Mokhtar Dahari (AMD) could benefit from a better understanding of CT and its potential to enhance youth player development. Furthermore, this study contributes to the development of scientific knowledge in the field of soccer training, helping to create age-appropriate, needs-based programs tailored to different age groups.

1.6.3 Future Research

This study opened avenues for future research, particularly I exploring the in-depth mechanism underpinning the CT intervention and its impact on improving soccer-related physical performance. For more robust findings, future studies could involve larger sample sizes of elite youth soccer players and utilize advanced equipment to study the effects of CT on their physical development in greater detail.

1.7 Definition of Terms

1.7.1 Complex Training (CT)

CT is a training program that combines both resistance training (RT) and plyometric training (PT) in the same session. During the training, high-intensity RT is performed, followed by similar biomechanically related movements from PT. Various combined RT and PT exercises were included in the training sessions.

1.7.2 Speed

Speed is defined as the body's ability to move as fast as possible over a certain distance. It refers to the shortest time required for the body to cover that distance. This study utilized the 20m sprint test to measure speed. The 20m sprint test is commonly used researchers to assess the speed performance of soccer players.

1.7.3 Change of Direction

Change of direction (COD) is one of the components of agility, known as the ability to make rapid, total-body movements and change direction when stimulus is given. In this context, however, it refers to pre-planned movements in response to a given stimulus. The test used is Arrowhead test, which is designed to measure COD for soccer players.

1.7.4 Power Performance

Power defined as the product of force, mass and acceleration, which describes the generation of force and movement speed used to produce explosive power movements. The test that will be used is the counter-movement jump (CMJ) test, as it is commonly used to assess player's jumping ability. For this study, the CMJ test is done through the My Jump 2 mobile application.

1.8 Limitation and Delimitation

1.8.1 Limitation

a) The current study did not directly assess the biological maturation (e.g., skeletal age, pubertal staging, or validated maturity-estimation methods);therefore, maturation was not analysed as a study variable Instead, analyses were based on chronological age groups. Biological maturation may vary within and between age groups, but it was not measured and was not inferred or treated as an explanatory variable in this thesis.

b) Participants may have consumed heavy meals before the testing session. However, the researcher have advised the participants to not have heavy meals at least two hours prior to testing.

c) Participants may not have been highly motivated or may not have put in full effort during the testing. To minimize this limitation, the researcher provides constant motivation to participants during data collection.

d) The relatively small sample size (Study 2) may have impacted the study's result.

1.8.2 Delimitation

a) This study only involved soccer players from the Sekolah Menengah Kebangsaan Sultan Idris Shah II, located in Gerik, Perak, aged between 15 and 18 years old

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter covers studies related to the current research. To gather information, the title of the recent study must be broken down into various variables. This chapter elaborates on previous studies regarding the physical demands in young soccer players and the effects of complex training (CT) on improving athletic performance in soccer, as well as other individual or team sports which related to the current study. Besides that, this chapter will further explore speed, change of direction (COD) and power performance which these three key factors that will be determine the effectiveness of CT by the end of the study.

2.2 Physical Demands in Youth Soccer Players

In recent years, modern soccer has underwent significant transformation, evolving into a fast-paced, intermittent sport (Michailidis et al., 2021; Yu et al., 2021; Andrašić et al., 2021). Modern soccer has evolved into combination of short bursts of high-intensity activities, including sprinting, running, jumping, duels, tackling, and frequent changes of direction (COD), as well as periods of walking and standing (Pavillon et al., 2021; Gualtieri et al., 2023). During a typical soccer match, players engage in high-intensity actions every 60 seconds and maximal efforts approximately every 4 minutes (Pavillon et al., 2021). On average, players perform over 1,200 unpredictable activity changes, which include 11-12% sprinting of the total distance covered, 1,200-1,400 direction changes, 30-40 tackles and jumps, and 90-140 ball interactions, such as passing, kicking, and dribbling (Yu et al., 2021; Negra et al., 2022; Hulton et al., 2022). Most of these actions are highly explosive and required high explosive lower limb demands (Križaj, 2020).

Ability to perform high-intensity actions are very important to success in soccer which by possessing great physiological abilities may benefits in optimizing performance and may enhance tactical implication of the coaches (Zghal et al., 2019; Yu et al., 2021; Keiner et al., 2021). The significance of possessing specific physical abilities like speed, change of direction (COD) and explosive power are crucial in the context of individual players and their impact on the team not only in adult but also in youth soccer game (Zghal et al., 2019; Andrašić et al., 2021). This is because, during the game, attackers are tasked with applying pressure and executing tackles on opponents, while defenders aim to minimize field space to restrict attacking movements and mitigate potential threats to the team (Andrašić et al., 2021). This trend underscores the increasingly athletic nature of soccer, where attributes such as strength, power and their derivatives, including sprinting, jumping and COD were correlated and play pivotal roles in determining success (Sonesson et al., 2020; Sariati et al., 2020; Keiner et al., 2021). This is supported by Križaj (2020) where in the study stated that there were moderate to strong relationship on how sprinting and changing direction required adequate amount of lower limb explosive power.

2.2.1 Speed

Speed is defined as the capacity to move or cover a distance quickly (Horicka et al., 2014; Shamshuddin et al., 2020). Yildiz et al., (2018) defined speed as high velocity running and ability to cover a distance from one point to another. In practical terms, it refers to the ability of the body to move the body as fast as possible over a set distance (Horicka et al., 2014; Krosta et al., 2020). Sprint performance is crucial in many sports, which has led successful athletes in their sport (Shamshuddin et al., 2020). As in soccer, it is one of the indicator to gain advantages in term of technical and tactical during the game (Yildiz et al., 2018). The utilization of speed is prevalent throughout both halves of a soccer game (Field et al., 2022).

Within soccer game situation, average distance covered by sprinting or speed is up to 110-330m respected to their playing position (Yildiz et al., 2018; Krosta et al., 2020). Saeidi and Khodamoradi (2017) highlight that professional athletes cover 5–10% less distance in the second half, particularly at medium intensity (11.1–19.0 km.h-1) and high (18.0–30.0 km.h-1) intensity speed categories. However, in a study by Reinhardt et al., (2019) indicated that average elite soccer players' distance cover for high intensity running is up to 24%-36% and for linear sprinting is up to 36%-63% of overall distance cover throughout the whole game. In aspect of youth soccer players, it was reported that the youth players approximately covered 6 to 8 km and performed average of 80 accelerations (>1 m·s−2) per match with a duration of 2 and 4 seconds each (Fernández-Galván et al., 2022). Sprint performance assessment has shown to be correlated to lower body muscle strength-power in youth soccer players and if the players possessed great sprinting capabilities may result in scoring advantages (Sonesson et al., 2020).

Speed involved acceleration and deceleration which both elements refer to the changes in velocity over time which acceleration specifically denotes the rate at which velocity increases, while deceleration describes the rate at which velocity decreases (Yildiz et al., 2018). In the 10-meter sprint, the stride frequency is high, the stride length is short, and there is maximum propulsion. Radnor et al. (2017) explained that sprinting relies on the stretch-shortening cycle (SSC), which involves an eccentric ‘stretching’ phase followed by a concentric ‘shortening’ phase. A series of concentric contractions are preceded by muscle stretching that are known as stretch-shortening cycle (SSC) (Alfonso et al., 2012). So, the evaluation of a series of concentric contractions is the main consideration for evaluating the ability to efficiently perform linear and COD sprints (Alfonso et al., 2012). This is supported by Shamshuddin et al., (2020) stated that sprinting required appropriate SSC capacity and musculoskeletal rigidity. During sprinting, the initial eccentric stretch, such as the preload on the muscle, has been found to improve the effectiveness of the subsequent concentric phase compared to performing a concentric action alone (Radnor et al., 2017). Besides that, in soccer, most action happened required speed to create crucial explosive actions (Komarudin et al., 2022). In the study stated that speed is essential for players, as it allows them to move quickly for tasks such as dribbling, passing, attacking, and running across the field. Additionally, speed is crucial for generating power in actions like kicking, jumping, and heading, as it works in conjunction with other physical abilities (Komarudin et al., 2022).

Thus, throughout the game, players tend to generate the greatest force in the shortest amount of time to either in technical or tactical aspect to gain advantages towards the opponent (Yildiz et al., 2018). This is supported by Saeidi and Khodamoradi (2017) from the coach’s tactical and technical point of view, speed is important for both attacking and defensive tactical play of the team. In the current study, speed analysed by using 20m Sprint Test which it was a maximal sprint effort testing (Madarsa et al., 2020) and often used to measure acceleration and maximum speed qualities (Brini et al., 2021). During the test, timing gates (Brower Timing System, USA) was used to records sprints time to the nearest 0.001 seconds (Murtagh et al., 2018) and to avoid any potential biased, the participants then underwent 8 weeks of CT to see the end results. All the procedures and protocols were explained in Chapter 3.

2.2.2 Change of Direction (COD)

Change of direction (COD) and agility used to have same definition but after continuous studies that been done throughout the years, COD had difference definition than agility (Giovanni et al., 2016; Falch et al., 2019). Andrašić et al., (2021) stated that in the last few decades, COD and reactive agility were considered to be the same skill. Past researcher has proposed these two skills are different two different and independent skills because of the presence of decision-making elements during movements execution (Ciocca et al., 2022). However, after continuous research been done, COD is described as a motion in which no immediately reaction to a stimulus is required, thus the path exchange is pre-deliberate or pre-planned (Andrašić et al., 2021). Basic agility definition is a rapid whole-body movement with change of speed or direction in response to a stimulus (Pojskic et al., 2018). In other study, agility is also known as the ability to maintain a stable body position while quickly changing direction without losing balance, body control, or speed (Shamshuddin et al., 2020). As for COD which defined as decelerating, altering direction, and then reaccelerating, is a crucial factor in soccer performance (Sánchez-López et al., 2023). In past study by Falch et al., (2019), COD also known as a speed component that has a rapid whole-body movement with changing direction in response to a stimulus and used a lot in soccer which it involved acceleration phase and a deceleration phase, followed by acceleration in a different direction.

COD is an important element in invasion sport like soccer (Sariati et al., 2020; Michailidis et al., 2021) which it is a common skill required to success in invasive sport like soccer (Andrašić et al., 2021). This is supported by Sariati et al., (2020) which stated that soccer is a sport that requires well developed speed, agility, balance and power either in elite or youth level. It enables them to evade opponents, adjust their positioning, and exploit gaps in the defence and whoever mastering this skill helps players maintain possession, create scoring opportunities, and enhance their overall agility on the field (Sariati et al., 2020). As according to Horníková and Zemková (2021), COD movements in in invading sport as soccer is determined by stride modifications, physical factors such as directly sprinting pace, and leg-muscle features, which consist of strength, power, and reactive strength. In a single game, soccer players will change running direction approximately every 2–4 seconds, and a total of 1,200–1400 times (Keiner et al., 2021). The players that has high COD ability could give an advantage in the game (Keiner et al., 2021). This is supported by Trecroci et al., (2020) COD movements such as side-steps, swerves, turns, crossover steps, and bypass manoeuvres are vital in soccer which they allow players to evade opponents effectively, create space for teammates and position themselves for scoring opportunities.

COD is known as independent skill which may cause differences between the players although they underwent similar training program especially in youth (Fiorili et al., 2017; Dugdale et al., 2020). Several factors influence COD execution such as technical aspects, observation, perception, anticipation and decision making during the movement (Sariati et al., 2020; Sinkovic et al., 2023). This is supported by Pojskic et al., (2018) and Dugdale et al., (2020) stated that individual technical skills and proper movement techniques may influence COD results. Sánchez-López et al., (2023) indicated that COD performance was neither influenced by the players' acceleration nor their linear speed but more on isolated factors such as technical efficiency, lower body braking force, contact time on the ground, correct pelvis alignment and foot contact on the ground during movements execution.

Past studies showed varied results in COD effects after underwent training especially in youth due to limited studies especially in youth, caused the most suitable soccer specific strength and conditioning training to enhance COD components still remain unclear (Sariati et al., 2020). In the current study, the researcher used arrowhead test to measure COD perfomance which this test often used to evaluate a soccer player's sprints that involved COD (Michailidis et al., 2021) and reliable in measuring COD in soccer (Rago et al., 2020). The researcher used complex training (CT) intervention training for the whole 8 weeks to analyse the effects towards COD. All the procedures and protocols were explained in Chapter 3.

2.2.3 Power Performance

Power is where force is the product of mass and acceleration (May et al., 2010) which in sport context referred to explosive movements execution, mechanisms used to produce power, focusing on such elements as velocity and force production which influenced by concentric and eccentric of muscle action (May et al., 2010). As for explosive power which defined as the dynamic strength and speed of muscle contractions, characterized by rapid and forceful movements (Darni and Elkadiowanda, 2019). Explosive power is a crucial motor skill in many sports including soccer (Abdelkader; 2016; Joksimović et al., 2019). In soccer where attributes such as strength, power and their derivatives, including sprinting, jumping and COD were correlated and play pivotal roles in determining success (Behm, 2018; Sonesson et al., 2020; Sariati et al., 2020; Keiner et al., 2021). Lower limb explosive power directly influences both sprinting and changing direction movements which youth players who possessed high level of explosive power could enhanced their ballistic movements translating into improving their performance in jumps, turning and sprinting ability (Franca et al., 2021; Cossio-Bolaños et al., 2021). This is because when executing specific explosive movements in soccer such as speed and changing direction required adequate explosive power capabilities which past studies stated that there were moderate to strong relationship between explosive power, speed and COD (Križaj, 2020).

Besides that, most skills involve in soccer require adequate amount of power, while shooting, sprinting and jumping require a lot of power output, rather than generating a lot of power on the muscles involved (Abdelkader, 2016). In soccer, about 80% of goals in matches are achieved through at least one powerful move, such as shooting, assisting in short or long passes, attempting to jump to the maximum height to score a head or quickly change direction In various goal situations in professional football (Abdelkader, 2016). As in coaches' point of view, explosive power is essential for executing powerful kicks, whether aiming for the goal, passing to a teammate, or making a swift run into the opponent's defensive zone which this capability allows players to perform dynamic actions with speed and strength, enhancing their effectiveness on the field (Darni and Elkadiowanda, 2019). During the explosive movements execution usually depends on contractile capacity for rapid force development—referred to as evoked explosive strength, voluntary nervous system, muscle capabilities, specifically regarding their muscle's stretch-shortening cycle (SSC) and the strength of the lower limb muscles and also maximum rate of force development (Kurihara et al., 2021; Maden-Wilkinson et al., 2021). Some of the previous studies indicated that some other factors that may influence explosive movements were Post-Activation Potential (PAP) effects, morphological changes and hormonal and cellular adaptations effects towards the muscles after underwent specific training program (Vanny and Moon, 2015; Lim and Barley, 2016; Gołaś et al., 2016; Jusoh et al., 2019; Thapa et al., 2020; Gharahdaghi et al., 2020; Grgic et al., 2021;

Zouhal et al., 2022).

Training to improve power is an important part of strength and conditioning programs (Yu et al., 2021). This is supported by Jusoh et al., (2019) stated that power is one of the most important physical components to gain success in modern soccer and power (strength-speed), speed and all the related factors are key contributor to the performance of the soccer team. Different kind of training approaches had been done to improve explosive power especially for the lower limb. Traditional resistance training (RT), plyometric training (PT) and complex training (CT) have been widely used in improving players' strength and explosive performances (Wang et al., 2023). As in this study, CT was used to identify the post-effects towards the players. To analyse this component, explosive power was analysed by counter-movement jump (CMJ) test which as according to Barker et al., (2018), CMJ is a great assessment to analyse lower body power and easier to perform rather than other jumping test like drop jumps or approach jumps. In the current study, instead of using traditional vertex, CMJ was observed through mobile application (My Jump 2) and recorded using a mobile smart phone (iPhone XR) (Haynes et al., 2019). The mobile application calculated the CMJ flight time by identifying the take-off and the landing of the video recorded which this application is a valid, reliable, useful and affordable tool for measuring jump performance for youth athlete (Bogataj et al., 2020). All the procedures and protocols were explained in Chapter 3.

2.3 Chronological Age and Biological Maturation in Relation to Physical Performances

Growth and biological maturation are fundamental process during adolescence that influence physical development and athletic performance. Growth refers to measureable changes in body size, such as height and body mass, whereas biological maturation refers to the progression toward adult physiological status. It is an important developmental processes during adolescence and are known to influence neuromuscular and morphological characteristics. Biological maturation refers to the progression toward adult status, whereas chronological age refers to the time elapsed since birth. Although chronological age is commonly used in sport settings to categorize youth athletes, it does not always accurately reflect individual differences in biological maturity. (Kumar et al., 2021; Towlson et al., 2020). During adolescence, the puberty period plays a crucial role in the acquisition of skills and the enhancement of performance in young athletes which suitable and appropriate training strategies during this period is very important to maintain good health, maximize sport-related performance and minimize the chances of injury (Campa and Greco, 2022).

Growth and maturity are generally assessed by both chronological age and biological age (Ke et al., 2021) which in the current study, we will highlighting influence of chronological age towards testing performance. Chronological age is simply calculated based on the date of birth (Currie, 2018) and is commonly used as the age category in the physical fitness standards globally (Ke et al., 2021). In aspect of sport specific performance like soccer, research examining the workloads of adolescents has predominantly utilized a chronological age-group methodology, in which they examine variations or similarities among different age groups based on their chronological age (Ke et al., 2021; Salter et al., 2022). As stated before, most actions executed in soccer are mostly need maximal force and highly explosive movements (Giminiani and Visca, 2017). Different age groups cause different outcomes in executing these movements (Salter et al., 2022).Ke et al. (2021) reported that chronological age is associated with physical fitness development. The ability to generate maximal force at specific velocities is influenced by morphological factors such as muscle cross-sectional area, muscle volume, pennation angle, fascicle length, and developmental progression (Philippaerts et al., 2005; Kumar et al., 2021). Several studies suggest that age-related developmental changes may influence physical performance (Lesinski et al., 2020; Giudicelli et al., 2021).

Research indicates that more physically developed adolescents often demonstrate superior strength and power performance compared to less developed peers (Pichardo et al., 2019), although evidence remains inconsistent (Zghal et al., 2019). Cross-sectional studies in youth sports have shown age-related differences in lower-body strength and performance, potentially linked to pubertal development and peak height velocity (Salter et al., 2020). Earlier developmental progression is often associated with greater body size, muscle mass, strength, and speed (Guimarães et al., 2019).

However, findings remain inconclusive due to limited research examining developmental influences in youth athletes, particularly within structured training interventions such as complex training (Rodriguez-Rosell et al., 2017; Peitz et al., 2018; Fernández-Galván et al., 2022).Current study did not use gold standard measurement to specifically assessing the influence of maturity on physical performances but just referring to past studies that stated chronological age might influence maturity to analyse the differences in physical testing results (Ke et al., 2021). This is because, although chronological age is one of the indicators to measure maturation in young athletes (Lesinski et al., 2020; Giudicelli et al., 2021) but different maturity status may influence the physical testing outcomes (Pichardo et al., 2019). Besides that, variations in the maturity status and timing among individuals have been found to impact the physical, psychological, and athletic development of adolescent males (Radnor et al., 2021) but lack of studies caused these statement remain unclear (Rodriguez-Rosell et al., 2017; Peitz et al., 2018; Giudicelli et al., 2021; Radnor et al., 2021; Fernández-Galván et al., 2022). Thus, the results reported by this current study helped to be one of evidence that shows differences between two chronological aged groups in term of speed, change of direction and explosive power and also after underwent complex training (CT) interventions.

2.4 Complex Training (CT)

The demands of modern soccer have drastically change in past few years which players need to have high level of power performance and cover greater distances with more frequent changes in intensity (Andrašić et al., 2021). Suitable training programs needed to be applied towards the players especially for the youth athletes (Zghal et al., 2019). There have been many debates about suitable training programs that could be applied to youth athletes because some past researcher stated that they are prone to injuries because of immaturity of the skeletal system (Peitz et al., 2018). Recent studies stated that appropriate training method that designed to develop physical qualities and neuromuscular control could offer positive effects to avoid injury while enhancing performance at the same time (Jayanthi et al., 2021). Combining different modes of exercises in single training session to meet physical demands of the athletes have been popular lately (Ali et al., 2019). Complex training (CT) has been found as suitable method to improve overall development of youth athletes' physical abilities that has been successfully applied to various sport including soccer (Cavaco et al., 2014; Wang et al., 2023). CT is a training that combined both resistance training (RT) and plyometric training (PT) in the same training session (Greenwood and Carter, 2014; Ali et al., 2019; Wang et al., 2023). CT protocols performed heavy load RT and followed by biomechanically similar explosive PT exercises (Abdelkader, 2016; Ali et al., 2019; Wang et al., 2023). Previous studies showed that combining RT with PT in the same training course has better outcomes in improving power and its' derivatives factors rather than RT and PT training separately (Zghal et al., 2019) and Ali et al., (2019) stated that CT could induced PT stimulus in enhancing explosive power and its' derivatives factors. This is supported by Kobal et al., (2017) stated that previous studies have revealed combining both RT and PT could induce greater implications and improvements in muscle capabilities when compared to RT and PT alone.

The first study about CT is in 1986 when Soviet Union used in their training which they used a heavy resistant exercise followed by a lighter exercise of a similar biomechanical movement pattern (Greenwood and Carter, 2014). The heavy resistant exercises are performed slow speed/ high load exercise (Greenwood and Carter, 2014). CT involved high intensities as 70–90% 1RM in a single session and plyometric training under low resistance (30% 1RM or body weight) (Angeliki-Nikoletta, 2015) as example, 5 repetitive movement (RM) squat (90° of knee flexion) without rest between repetitions which then with one set of five repetitions of each individual's drop jump height with a 5 s rest between repetitions (Chen et al., 2017). Improvement of muscle explosiveness after being provoked maximum or near maximum muscle contraction is the logic behind CT intervention training (Freitas et al., 2017; Ali et al., 2019). CT could elicit the improvement of neuro-muscular adaptation which help to produce more power during movement execution (Li et al., 2019). These phenomenon also known as improvement of Post-Activation Potentiation (PAP) response which defined as enhanced neuro-muscular condition observed in the skeletal muscle after an initial bout of heavy resistance exercise (Lim and Barley, 2016; Poulos et al., 2018) which in study by Abdelkader (2016) defined PAP as force wielded by the muscle influenced by the previous contractile of the muscle. This adaptation cause higher recruitment of motor units, synchronization and central input of motor units, and then help to induce the phosphorylation of myosin light chains, which makes the myofilaments become more sensitive to the calcium and may also reduce pre-synaptic inhibition (Greenwood and Carter, 2014; Li et al., 2019).

CT proposed physiological mechanisms enhancement for regulation of myosin light chain phosphorylation which increase the sensitivity of actin-myosin for calcium ions (Ca2+), alter myosin head structure and produce higher cross-bridge force output and muscle pre-contraction can increase excitation potential across the spinal cord resulting in greater motor unit recruitment (Chen et al., 2017; Poulos et al., 2018). This is supported by Brito et al., (2014) which in the study stated that movement executed in CT training cause voluntary conditioned contractions, usually performed at or near maximum intensity, which may increase the peak force and force development speed during subsequent twitch contractions (Brito et al., 2014) which means that CT will help the muscles to increase their power output capabilities to perform at certain rate. Jusoh et al., (2019) stated that CT could enhance the coordination of motor unit activation; thought to result in reduced contact duration and increased peak height, thereby amplifying the impact of the stretch-shortening cycle (SSC) in the subsequent plyometric phase (Jusoh et al., 2019).

Align with the PAP response, CT may induced the morphological changes. This is because CT may provide additive benefits in increasing the targeted muscle size (Grgic et al., 2021). Past studies have shown CT may result in increasing muscle thickness and higher muscle size improvement when implemented towards the athletes (Grgic, et al., 2021) which in the same journal also stated that combined of RT and PT induced significant changes in muscle cross-sectional areas and positive changes in muscle size but more studies needed to support this findings. This is supported by Schneiker et al., (2023) strength-power training regime caused the improvement of muscle cross-sectional area, muscle architectural changes, muscle hypertrophy and muscle tendinous which these neuro-muscular and morphological adaptation significantly improve the explosive movement execution performance. This is supported by Grgic et al., (2021) which the study indicated that improvement of type IIx muscle fibres which associates with the response towards to CT intervention movements and PAP response cause greater potential of hypertrophy effects (Grgic, et al., 2021). Even though there were quite arguments that correlates muscle hypertrophy to maximal strength production because some past studies indicates that changes in strength may occur without change in muscle size, but we must not exclude muscle size improvement may contribute to maximal strength production (Vigotsky et al., 2018). This is supported by Reggiani and Schiaffino (2020) stated that changes in the athletes' muscle architectural and size caused contractile performance and higher force generation of the muscle during movements execution. This is also supported by Thapa et al., (2020) which in the study stated that power production increased due to higher type IIx muscle fibres recruitment that cause greater contraction velocity, greater explosive power production and rate of force development compared to type

IIA and type I muscle fibres.

Besides that, some of past studies also showed contrary results after given CT training program. This could be seen in Chen et al., (2017) as stated in Jusoh al.,(2019) which in the study, the researcher did not recommended CT to be applied in team training regime because some athletes may negatively impact their performance, while others showed improvement. However, this statement is due to further confirmation because of different protocols used (Jusoh et al., 2019). A previous study observes that there was a small positive effect towards jumping performance with 2 times per week frequency of training for a whole 6 weeks (Freitas et al., 2017) however, in another study by Freitas et al. (2017) shows that within 6 weeks of training, it indicates that jumping performance could only be improved by applying CT protocol with a duration of training of more than 6 weeks and the total CT sessions must be more. Christou et al. (2006) as stated in Cavaco et al., (2014) suggested that in term of soccer, specific strength training could benefit the overall development of young athletes' physical fitness. This is supported by Maio Alves et al., (2010) which in the study, after six weeks of training in a study of youth Portuguese soccer players, the result showed speed and jump performance had improved significantly. To create more concrete evidence to the effectiveness of CT and to fill the gap that being left, this current study followed Abdelkader (2017) CT protocols and implemented 3 times per week of training and was done for the whole 8 weeks. This is supported by Jovanovic et al., (2011) which stated that long-term adaptations of training will result in higher power production.

Despite all the existed outcomes evidences of the effectiveness of CT, there were still limited studies regarding the effects of different moderator variables on physiological adaptive processes following RT and PT programs in youth (Peitz et al., 2018). In addition, there are still limited studies observing the change of physical performance between different ages or maturity groups after undergoing the same training program (Rodriguez-Rosell et al., 2017) especially by using CT. Most of the past studies usually used older participants rather than youth to demonstrate the effectiveness of combined training like CT (Zghal et al., 2019). This is supported by Peitz et al., (2018) that stated more studies need to be done to compare the different age groups especially in young athletes. Hence, this current study will be one of the evidence to support the effectiveness of CT in youth which CT showed to be safe among young soccer players and it is recommended for the improvement of their sport performance especially in aspect of soccer (Kobal et al., 2017).

2.5 Effects of Complex Training (CT)

There are various studies that stated the effects of CT.

Table 2.1
Summary of Studies on the Effect of CT

Author, Year	participants Type/numbers	Age	CT Method	Findings
Kuan et al., (2018)	Weightlifting n=17	15.7 ± 0.93 years	They trained for 6 weeks (2 sessions per week). Rest Interval Between Sets: 3min Week 1, Week 5 & Week 9 Pre-Test & Post-Test Week 2-4 Day 1:75-82% 1RM RT, Sets/Reps:3x5-6 , PT: Sets/Reps:3x5-7 Day 2: 60-67% 1RM RT, Sets/Reps: 3x5-6, PT: Sets/Reps: 3x4-6 Week 6-8 Day 1: 85-90% 1RM RT, Sets/Reps: 3x3-4, PT: Sets/Reps: 3x3-5 Day 2: 45-55% 1RM RT, Sets/Reps: 3x3-4, PT: 3x3-4	CT increase jumping performance in CMJ
Kobal et al., (2017)	Soccer n= 27	18.9 ± 0.6 years	They trained 8 week Rest Interval Between Sets: 3min Week 1-4 RT:60-70% 1RM, Sets/Reps:3-4x8-10, PT: 3-4x12/30-35cm Week 5-8 RT: 70-80% 1RM, Sets/Reps:3-5x6, PT: 3-5x10/45cm	CT improve jumping performance No significant improvement of speed
Abdelkader (2016)	Soccer n= 10	20.7 ± 1.2 years	They trained 8 weeks (3 sessions per week) Rest Interval Between Sets: 2-3min Week 1-4 RT: 70-85% 1RM, Sets/Reps: 2x5-8, PT: Sets/Reps: 1-2x5-10 Week 5-8 RT: 70-95% 1RM, Sets/Reps: 1x3-8, PT: Sets/Reps: 1x4-10	CT increase jumping performance (CMJ)

Cavaco et al., (2014)	Soccer n= 16	13.80 ± 0.45 years & 14.20 ± 0.45 years	6 weeks CT program (1-2 sessions per week) Rest Interval Between Sets: 3min 1st station 85% of 1RM squat, Sets/Reps: 3x6 at, 15 m plus top speed and cross 2nd station 85% of 1RM squat, Sets/Reps: 3x6 plus agility with the ball and shot at the goal separated. The load in the squat exercise was increased by 5% from initial 1RM each 2 weeks.	CT did not improve speed and agility components
Brito et al., (2014)	Soccer n= 57	20.3 ± 1.6 years	9weeks (3 sessions per week) Rest Interval not stated 1st Station RT: 85% 1RM Squat, Sets/Reps: 1x6, PT: Sets/Reps: 1x5m 2nd Station RT: 90% 1RM calf extension, Sets/Reps: 1x6, PT: 1x 3-8	CT improved speed. No significance effects in jumping performance (CMJ)
Maio Alves et al., (2010)	Soccer n=23	17 ± 0.6 years	6 weeks (1-2 sessions per week) Rest interval not stated 1st Station 85% 1RM (Reps: 6) of Squat 1 set of 5 meters high skipping 5 meters sprint. 2nd Station 90% 1RM (Reps: 6) of calf extension 8 vertical jumps 3 high ball headers 3rd Station 80% 1RM (Reps: 6) of leg extension 6 jumps from the seated position 3 drops jumps (60 cm) The load was increased at 5% from 1RM each 2 weeks of training.	CT improve speed and jumping performance

Based on the table 2.1 above, previous studies have provided substantial evidence because most of the results show positive effects when applying the CT towards athletes. As the result found in Kobal et al., (2017), the findings showed that after underwent 8 weeks of CT, the CT groups increased their CMJ height. Same finding was found in Abdelkader (2016) which in the study, statistical significance differences between pre and post-test measurements of the CMJ after underwent 8 weeks of CT. In Maio Alves et al., (2010) also found that CT is appropriate strategy to improve soccer players' speed and jumping performance. In term of other sport, the same finding was found in Kuan et al., (2018) where in the study, CMJ performances was significantly improve between pre and post-test after underwent 6 weeks of CT.

Cavaco et al., (2014) found no significance differences in speed and agility related components after underwent 6 weeks CT program (1-2 sessions per week). Align with the result in Cavaco et al., (2014), no significance differences were found in the speed performance between the pre and post-test results after underwent CT programs. This is because speed may affected due to inter-individual variability like technical factor which these factor may influence the end result (Cavaco et al., 2014). In agility or changing direction which these components are more dependent on factors of motor control, rather than maximal strength or lower limb muscular power. This is supported by (Hammami et al., 2018) technical factors and athletes' training status during the whole training intervention period and also during the testing may influence the end results. Running technique quality which these factors may influence the result of speed and agility-related components which it is possible that individuals may have adopted a more effective technique, resulting in a decrease in their body mass and may experience favourable psychological or hormonal influences that can impact their performance during testing (Cavaco et al., 2014; Pojskic et al., 2018). Contrary to this findings, Brito et al., (2014), speed were affected at the end results after underwent 9 weeks of CT but no significance differences were found in jumping performance.

Based on the journal above, some findings shown difference at the end result either in speed or jumping performance but some did not affected and not significantly improved after underwent weeks of CT intervention. Most of the past studies stated above utilize 4 to 9 weeks of training with different approaches or protocols used in terms of volume/ training days, intensities and number or type of exercises used. Besides that, most of the studies only focusing on improving strength, power and speed. Very limited of the past findings try to improve change of direction (COD). As for the current study, as stated before, the researcher will use CT protocol from Abdelkader (2016) by utilizing 8 weeks of training with 3 days of training sessions per week with different kind of exercises involved to prove the effectiveness of CT on improving 3 selected physical fitness which are speed, COD and power performance towards U-15 and U-18 soccer players.

2.6 Summary

In conclusion, speed, change of direction (COD), and explosive power are crucial elements that significantly enhance soccer player’s performance. Speed enables players to outpace opponents, make swift transitions, and capitalize on counter-attacks. COD allows for effective dribbling, precise defensive positioning, and adaptability in dynamic play situations while explosive power contributes to quick acceleration, more powerful shooting, and dominant aerial play. Together, these attributes not only improve individual skills but also improve team’s performances, giving advantages to them for achieving success on the soccer field. This is because, by possessing great physiological abilities may help in optimizing performance and could enhance tactical implication of the coaches which then cause the team to gain advantages during the game (Zghal et al., 2019; Yu et al., 2021; Keiner et al., 2021). Zghal et al., (2019) supported this statement by stating that both team and individual performances may benefit by having great speed, COD and explosive power. This is because strength, power and their derivatives, including sprinting, jumping and COD were correlated and played important roles in success in soccer (Sonesson et al., 2020; Sariati et al., 2020; Keiner et al., 2021).

Thus, strength and conditioning coach must properly conducted suitable training program especially for youth players to enhance all the physical capabilities so that they met the physical demand to success in soccer. The coach must to make sure that the training could achieve great long-term physical development and try to maximize a young player's performance potential by the time they reach full maturity, specific and appropriate injury-free training program must be implemented to gradually increase athletes’ physical capabilities (Trecroci et al., 2020; Magallanes et al., 2022). As stated in the literature review, CT is one of the training method that combined both RT and PT in the same training program to boost players’ explosive power (Greenwood and Carter, 2014; Wang et al., 2023) and its derivatives which the compnents are crucial to success in soccer (Zghal et al., 2019). Eventhough there are still limited studies observing the change of physical performance between different ages or maturity groups after undergoing the same training program (Rodriguez-Rosell et al., 2017) especially by using CT, and limited study that explores changes in physical performance among different ages and maturity (Giudicelli et al., 2021; Fernández-Galván et al., 2022), this current study could give some information and input on the effectiveness of CT and the same time give valuable information for coaches by highlighting the correlation between age and sport performance. By recognizing and accommodating individual differences, coaches ccould optimize training programs effects especially in youth soccer. Most of the past studies usually used older participants rather than youth to demonstrate the effectiveness of combined training like CT (Firas Zghal et al., 2019). This is supported by Peitz et al., (2018) that stated more studies need to be done to compare the different age groups especially in young athletes. Hence, this current study will be one of the evidence to support the changes in physical performance among different ages and maturity (Giudicelli et al., 2021; Fernández-Galván et al., 2022)

CHAPTER 3
CHRONOLOGICAL AGE AND PERFORMANCE DIFFERENCES: A COMPARATIVE ANALYSIS OF SPEED, CHANGE OF DIRECTION, AND EXPLOSIVE POWER AMONG U-15 AND U-18 SOCCER PLAYERS

3.1 Abstract

Chronological age is calculated from a single time point based on an individual’s date of birth and changes in physical fitness may vary among individuals. Thus, this study aimed to examine disparities in speed, change of direction and explosive power performance between two competitive age group. Thirty soccer players (n=30) were recruited from a secondary school, comprising of two age groups: under 15 (n=15) and under 18 (n=15). The participants underwent three physical tests assessing speed, change of direction and explosive power performance. The findings revealed significant differences were found in explosive power performance (p=0.04) and speed performance (p=0.05), while change of direction results did not reach significance. These outcomes underscore the potential influence of different level of age differences on sport-related performance.

Keywords: soccer, speed, change of direction, explosive power, age and maturity impact

3.2 Introduction

Over the recent years, modern soccer had undergone a profound transformation, evolving into a dynamic and high-paced intermittent sport game (Michailidis et al., 2021; Yu et al., 2021; Andrašić et al., 2021). Soccer nowadays has been characterized by a blend of short-duration, high intensity activities, including sprinting, running, jumping, duels, tackling, change of direction (COD), and various instances of walking and standing (Pavillon et al., 2021; Gualtieri et al., 2023). In a typical soccer game, players performed many high-intensity movements every 60 seconds and maximal efforts every 4 minutes (Pavillon et al., 2021). It was reported that overall players perform more than 1200 unpredictable changes in activity, which comprises of up to 11-12% of sprinting from overall total distances covered, 1200-1400 changing direction and 30–40 tackling and jumping and between 90 to 140 interaction with the ball which includes passing, kicking and also dribbling (Yu et al., 2021; Negra et al., 2022; Hulton et al., 2022) which most of the actions involved in soccer are mostly highly explosive (Križaj, 2020).

In this current study, our focus centres on two specific age groups to examine the effects of CT. The rationale for selecting these age groups stems from a scarcity of research that explores changes in physical performance among different ages and maturity (Giudicelli et al., 2021; Fernández-Galván et al., 2022). Growth and maturity are usually assessed by both chronological age and biological age (Ke et al., 2021). Current study used chronological age as primary measure to assess maturity to analyse the differences between both studied groups. This is supported by Ke et al., (2021) and Salter et al., (2022) which stated that in aspect of sport specific performance like soccer, research examining the workloads of adolescents has predominantly utilized a chronological age-group methodology, in which they examine variations or similarities among different age groups based on their chronological age. Existing evidence suggests that physically mature boys generally demonstrate better performance than their less mature counterparts (Pichardo et al., 2019) which as according to Salter et al., (2022), different age groups cause different outcomes in executing sport specific movements. However, limited studies exist to robustly support this observation (Zghal et al., 2019). This is supported by Soneeson et al., (2020) where the study stated that previous evidences shown that performance of the youth athlete became plateau after the age of 15 years old. To contribute more substantial evidence supporting disparities in performance between various age, the current study seeks to investigate the differences in speed, change of direction and power performance among U-15 and U-18 soccer players.

3.3 Method

3.3.1 Research Design

This study adopted an experimental design with a causal-comparative research framework to compare three physical tests between the two age groups of participants. The aim was to analyse the differences in speed, change of direction (COD), and power performance between U-15 and U-18 soccer players. The three physical tests conducted included the 20m sprint test, the arrowhead test, and the counter-movement jump (CMJ) test.

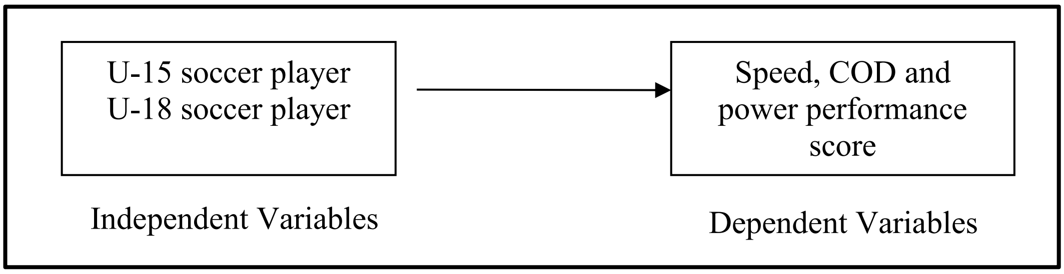

Figure 3.1 Conceptual Framework

3.3.2 Population/ Sample/participants/ Sampling Techniques

A priori power analysis was conducted using G*Power 3.1 to determine the minimum required sample size. Assuming a moderate effect size (f = 0.25), an alpha level of 0.05, and statistical power of 0.80 for repeated measures ANOVA, the recommended minimum total sample size was [insert calculated number]. The final sample size met/exceeded this requirement, indicating sufficient power to detect meaningful differences between groups. Participants were recruited using total population sampling from eligible U-15 and U-18 soccer players within the selected school. All players who met the inclusion criteria were invited to participate to enhance representativeness. Although the sample was limited to one institution, which may affect external generalisability, the controlled training environment increased internal validity and allowed consistent implementation of the intervention protocol.

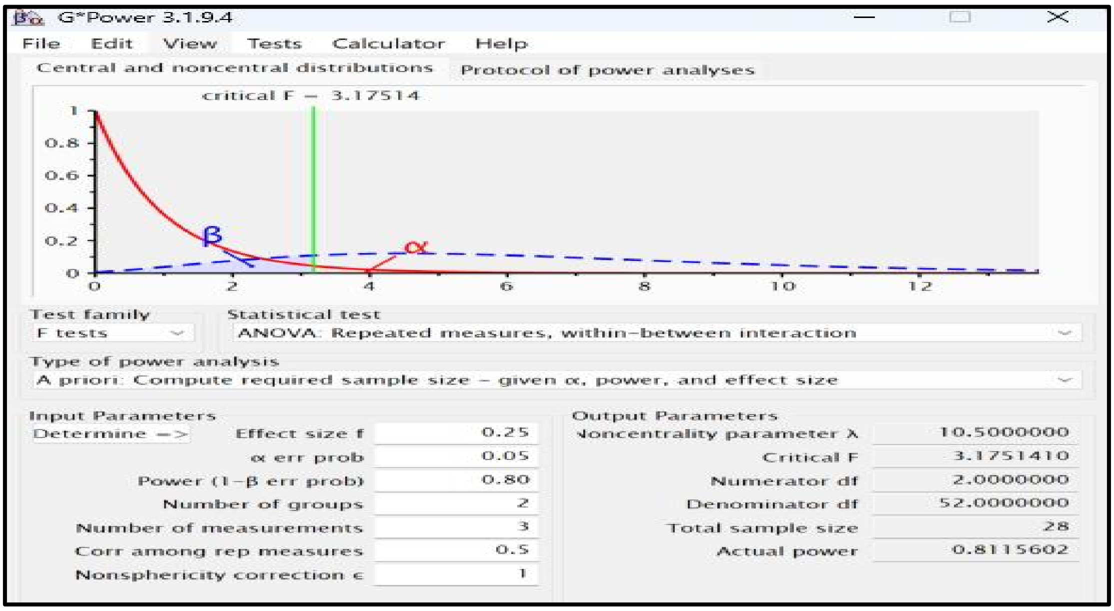

Figure 3.2 CG*Power 3.1

The participants in this study were soccer players from Sultan Idris Shah II Secondary School, Malaysia. The school was selected due to its' sport specific program which known as District Training Centre which the main sport is soccer. The school's athletes/ players started joining the soccer program since 13 years old which they were properly selected from 'Talent Identification Program (TID)' when they were 12 years old (Primary school). When they joined the program, they will involve in 5-6 times per week of training regime like normal sport school which consisted of soccer specific technical and tactical training and also numerous physical training. The program aimed to success in any open tournaments and state level competitions (Majlis Sukan Sekolah-Sekolah Negeri/ MSSN). Besides that, the school tend to send players to play for Majlis Sukan Sekolah-Sekolah Malaysia (MSSM). The current study used purposive sampling technique, aiming to achieve at least 80% confidence in the sample size and to detect differences of speed, COD and power performance between U-15 and U-18 soccer players. A total of thirty players (n=30) were selected for this study. The participants were recruited from two age groups; Under 15 (U-15): (n=15, mean ± SD; age = 14.47 ± 0.81 years; height = 164.60 ± 6.44 cm; body mass = 55.04 ± 12.64 kg) and Under 18 (U-18) (n=15, mean ± SD; age = 16.27 ± 0.44 years; height = 167.53 ± 4.91 cm; body mass = 56.71 ± 7.59 kg).

Participants were required to be injury-free for at least six months in the lower limb regions before testing. A health screening process was conducted by the researcher before testing began to identify any potential health risks that might have excluded participants from the study. The screening included the Physical Activity Readiness Questionnaire (PAR-Q), which determined whether the players had any medical conditions in the past six months that could affect their participation. The questionnaire consisted of three sections; Section A: Personal Details; Section B: PAR-Q; and Section C: Parental Permission/Assent Form). Sections A and B were collected before testing, while section C, which required parental permission/assent to participate in the study, was given to the participants' guardians for signing. Players who had lower limb injuries or did not pass the PAR-Q were excluded from the study.

3.3.3 Instrument and Instrumentation

3.3.3.1 Instrument

a) Health Screening

The health screening process was conducted by the researcher before testing began to identify any health risks that could cause players to be excluded from the program. The screening included the Physical Activity Readiness Questionnaire (PAR-Q), which was used to determine whether the players had any medical conditions in the past six months before the test. The questionnaire consisted of three sections: Section A (Personal Details), Section B (PAR-Q), and Section C (Parental Permission/Assent Form). Sections A and B were collected, while Section C, which contained the Parental Permission/Assent to Participate in a Research Study Form, was given to the participants' guardians for signing. Participants who had any lower limb injuries or did not pass the PAR-Q were excluded from the study.

b) Anthropometric Measurements

Standing height was measured using stadiometer, and participants' weight was recorded using a digital weighing scale.

3.3.3.2 Instrumentation

a) Study Protocol

i. 20m Sprint Test

20m Sprint Test was used to measure speed. The test involved maximal sprint effort testing (Madarsa et al., 2020) and often used to measure acceleration and maximum speed qualities (Brini et al., 2021). During the test, timing gates (Brower Timing System, USA) was used to records sprints time to the nearest 0.001 seconds (Murtagh et al., 2018) and to avoid any potential biased. The timing gate was placed at point A (0m) at the starting line and at the finish line/ point B (20m) which it recorded photocells with 1milisecond accuracy (Brini et al., 2021). Participants need to perform three maximal sprint efforts for 20m distance (Brini et al., 2021) as in Figure 3.2, separated by approximately 3 minutes of passive recovery. The best time between three efforts was recorded to the nearest two decimals.

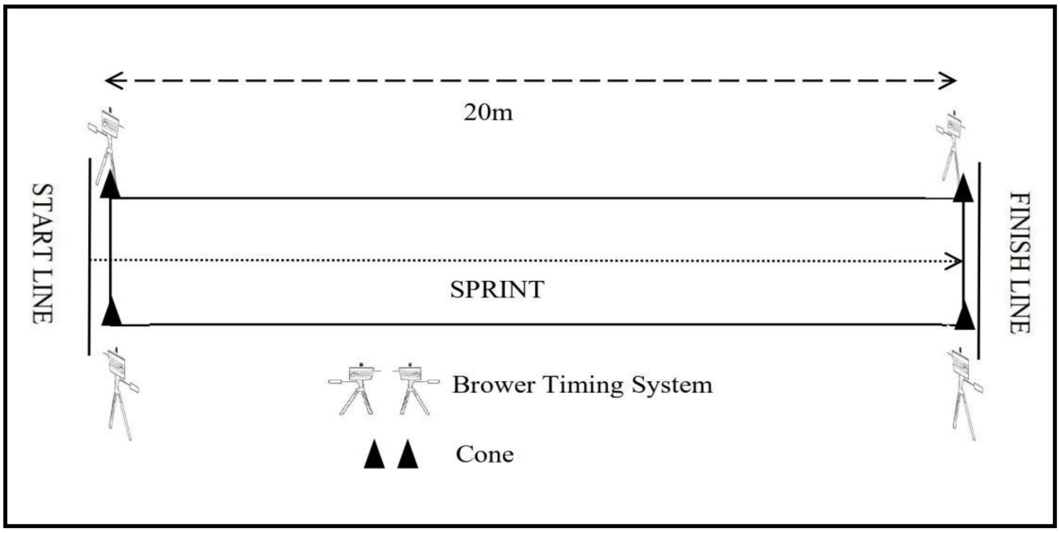

Figure 3.3 20m Sprint Test

20m Sprint Test Procedures

a) Participants were required to stand at the starting line from a standing position. They started when the researcher blew the whistle.

b) The participants were required to make maximal sprint efforts over 20m distance during the test, as shown in Figure 3.3

c) The three sprints were separated by approximately 3 minutes of passive recovery.

d) Each participants was required to complete all three intervals.

e) The best time of the three efforts was recorded to the nearest two decimal places.

ii. Arrowhead Test

The Arrowhead test was used to measure change of direction (COD), and it was shown to evaluate a soccer player's capacity for longer distance sprints involving COD (Michailidis et al., 2021) and was found to be reliable in measuring COD in soccer (Rago et al., 2020). The timing gates were placed at the starting and finishing points, as shown in Figure 3.3. The participants started with their foot behind the starting line in a sprint start position. The timer started when the whistle was blown, and the participants began running, passing the timing gates. The participants were required to complete six trials.

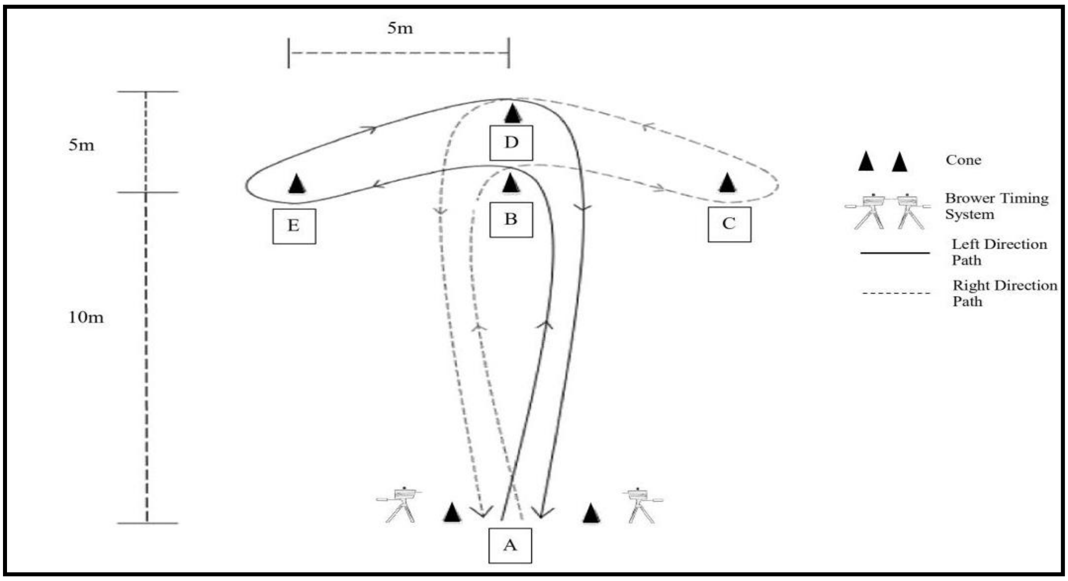

Figure 3.4 Arrowhead Test

Arrowhead Test Procedures

a) At first, from A, the participants needed to sprint as fast as possible to the B, turned to run around the side of either cone C or cone E, then to around the cone D and ran back to the starting/finish line (Figure 3.4).

b) The trial did not count if they step over the cone instead of around it.

c) The best time between the 3 trials were recorded to be analysed.

d) The tests were done on the right side first before left and they rotated alphabetically by surname for each trials.

e) This provided approximately 3 minutes of rest which was enough recovery for the participants to do the next trials.

iii. Counter-Movement Jump (CMJ) Test

The explosive power was assessed using the counter-movement jump (CMJ) test. According to Barker et al., (2018), the CMJ is an effective assessment to observe lower body power abilities and easier to perform than other jumping tests, such as drop jumps or approach jumps. Current study used mobile application (My Jump 2) to analyse CMJ and recorded with a smartphone (Iphone XR) (Haynes et al., 2019) instead of using traditional VertecTM tool.

The mobile application determines the jump height using the equation $h = t2 \times 1.22625$ where h represents the jump height (meters) and t represents flight time (seconds). During testing, the application automatically calculated the CMJ flight time by identifying the take-off and landing in the recorded video (Bogataj et al., 2020). My Jump 2 has been widely used as a replacement for the traditional VertecTM, as it is reliable, valid and affordable tool to measure jumping performance in youth athletes (Bogataj et al., 2020).

Figure 3.5 My Jump 2 Application.
Source: Balsalobre-Fernández, C. (n.d.). Carlos Balsalobre, PhD.
https://carlosbalsalobre.com/index.html

CMJ Test Procedures

a) At First, the researcher put the personal data of the participants in the My Jump 2 application (Figure 3.5).

b) Then, the researcher selected 'Vertical Jump' and chose 'Counter-Movement Jump' (CMJ) (Figure 3.6).

c) The researcher recorded the movement from the same position and at the same distance from the participants, which were 1.5m apart according to the manufacturer's instructions.

d) The CMJ starting position was a standing position with knees fully extended with the feet shoulder-width apart while maintaining a straight torso.

e) Participants needed to keep their hands on their hips while doing the jumping.

f) The participants needed to perform a quick downward movement of approximately 90◦ of knee flexion and then a fast-upward movement to jump as Figure 3.7.

g) They needed to jumps as high as possible when instructed.

h) My Jump 2 application calculated the jump height by manually selecting the take-off frame and landing frame as seen in Figure 3.8.

i) The participants needed to do 3 trials for this test.

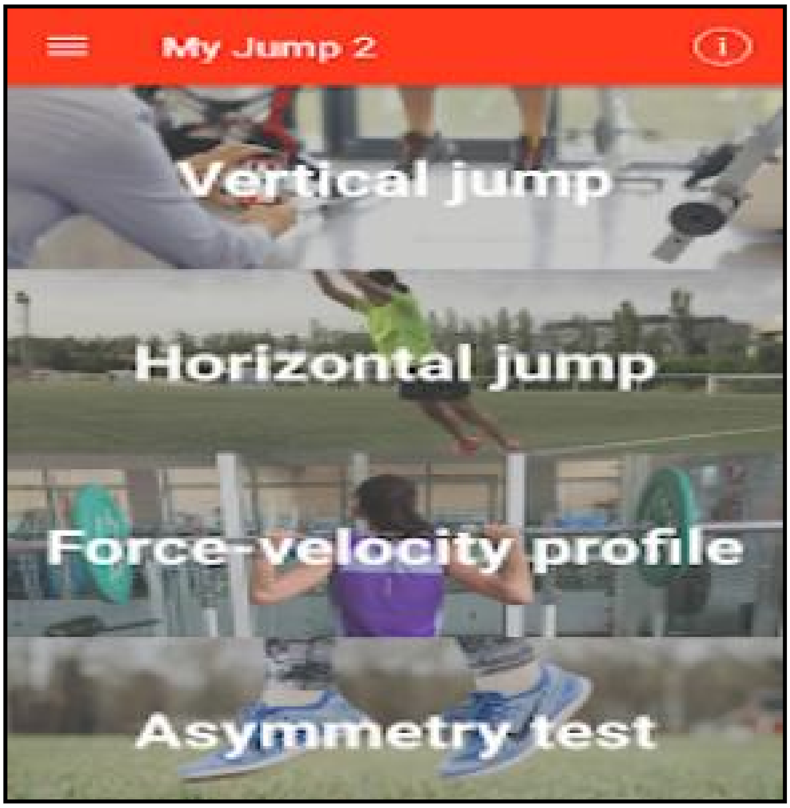

Figure 3.6 My Jump 2 Test Selection.
Source: APKPure. (2022, November 1). My Jump 2: Measure your jump Latest Version 2.2.6 for Android. APKPure.com.https://apkpure.com/my-jump-2-measure-your-jump/com.my.jump


Figure 3.7 Counter-Movement Jump (CMJ)

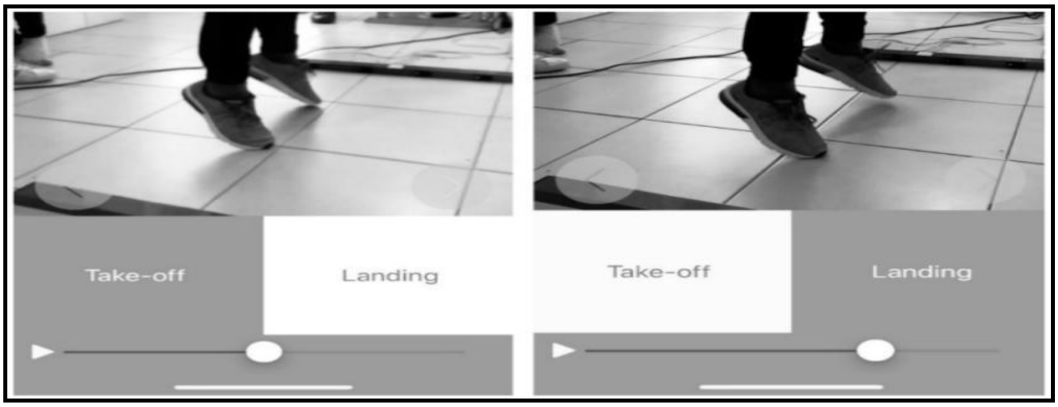

Figure 3.8 Landing Frame and Take-Off Frame.
Source: Bogataj, Š., Pajek, M., Andrašić, S., & Trajković, N. (2020)

3.4 Data Collection

This study has been ethically approved by the UiTM Research Ethics Committee (REC/10/2022 CPG/MR/245). Two days (48hours) before the research process started, the researcher met with the participants to explain about the study. The explanation covered the entire study process, including the required tests: the 20m sprint test, arrowhead test and counter-movement jump test. The researcher then conducted health screenings and obtained informed consent, which consist of three sections: Section A (Personal Detail), section B (Physical Activity Readiness Questionnaire) and section C (Assent Form). During the 48 hours prior to testing, participants were advised avoid strenuous physical activities and refrain from consuming heavy meals two hours prior to testing.

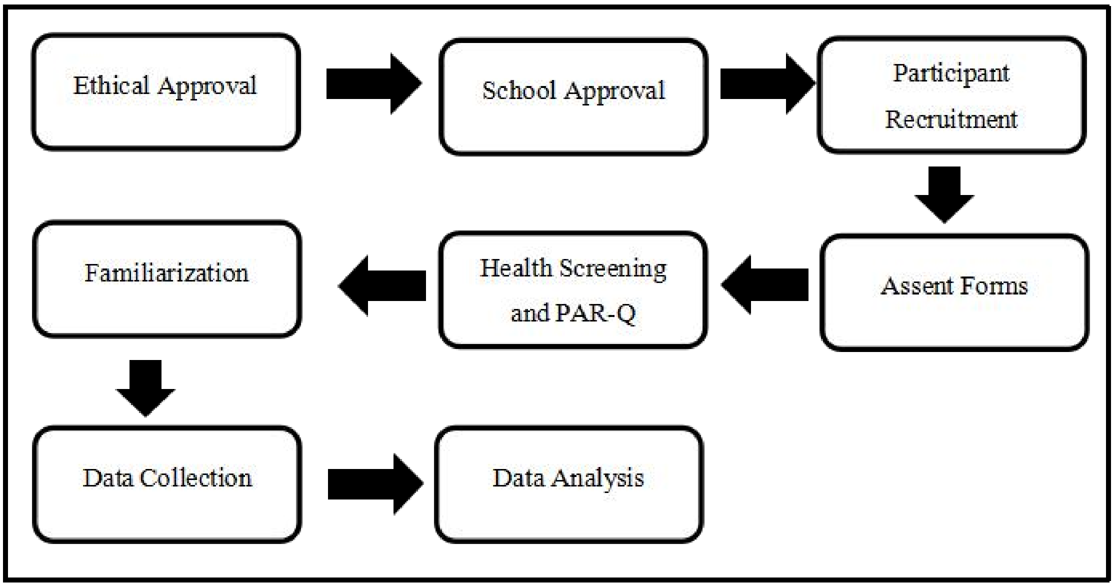

Figure 3.9 Research Flow Chart.

After two days, the researcher met with the participants again to begin the research process. Before starting, the researcher collected the assent forms from the participants. The testing started with proper warm up and familiarization of the tests involved so that they will have a better view and knew how to perform the test with proper techniques. The actual procedures on the testing day were as follows:

3.4.1 Warm Up Protocol and Familiarization

A standardized warm up was conducted for approximately 10 minutes, led by the researcher. The warm-up consisted of a 5-minute dynamic warm up and movement drills. After that, testing familiarization was conducted, during which the researcher demonstrated the correct movements and procedures for the tests. The participants then practiced each assessment to ensure they were familiar with the testing procedures.

3.4.2 Testing Procedures

Participants started with sequences of 20m sprint test (3 trials), arrowhead test (3 trials for the right direction and 3 for the left direction) and counter-movement jump (CMJ) test (3 trials). After finished, they did the cooling down led by the researcher

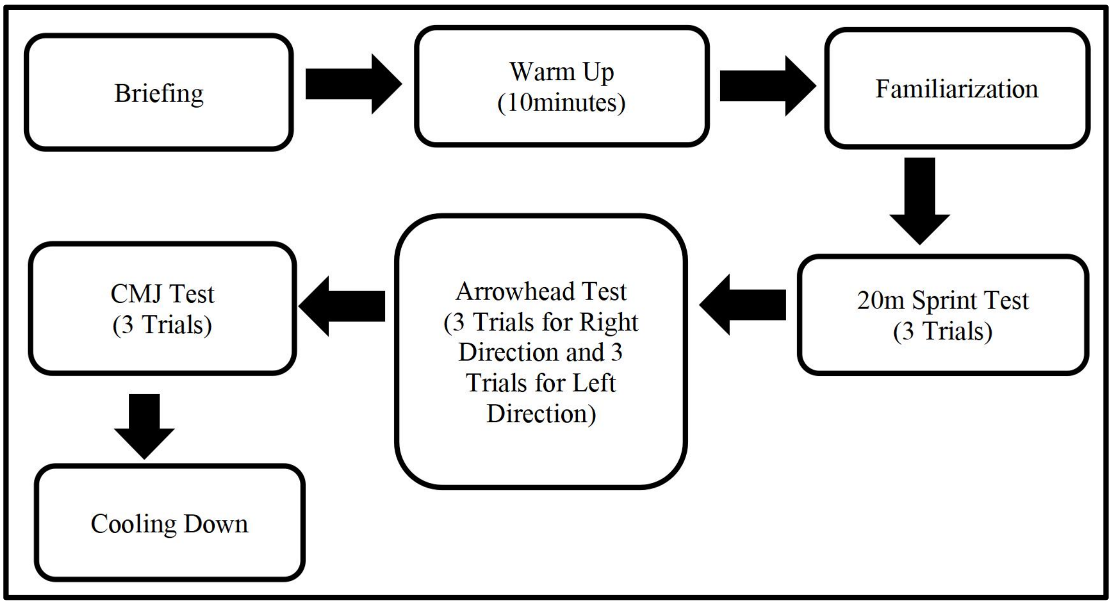

Figure 3.10 Data Collection Procedures.

3.5 Data Analysis

Descriptive statistics were used to describe the demographic data, which included participants' height (cm), weight (kg), and age (years). Data were presented as means and standard deviations (SD) in both the text and tables. Additionally, the mean and SD of the scores were also presented in the descriptive table. SPSS (Version 25, SPSS) was used for statistical analyses. For inferential statistics, an Independent T-Test was conducted to determine differences in speed, change of direction, and power performance between U-15 and U-18 soccer players. These statistics were reported using mean and standard deviation, with significance set at $p \leq 0.05$.

3.6 Result

The aim was to investigate differences in speed, change of direction, and power performance between U-15 and U-18 soccer players. This study employed a causal-comparative research design, involving three physical tests and assessments. The three physical tests conducted were the 20m sprint test, the arrowhead test, and the counter-movement jump (CMJ) test. The result of this study is shown in mean and standard deviations.

3.6.1 Descriptive Statistics

Table 3.1
Demographic Comparison between U-15 and U-18

Variables	N	U-15 (Mean ± SD)	U-18 (Mean ± SD)
Age (years)	30	14.47 ± 0.81	16.27 ± 0.44
Weight (kg)	30	55.04 ± 12.64	56.71 ± 7.59
Height (cm)	30	164.60 ± 6.44	167.53 ± 4.91

Table 3.1 presents the demographic data of the participants in this study. Three variables were observed; age (years), weight (kg), and height (m), along with their mean and standard deviation (SD) values. A total of 30 participants (n = 30) were included in this study, with 15 players in each group (U15: n=15, U18: n=15).

Table 3.2.
Descriptive Analysis between U-15 and U-18 Soccer Players

Variables	U-15 (n=15) (Mean ± SD)	U-18 (n=15) (Mean ± SD)
20m Sprint Test (s)	3.23 ± 0.09	3.16 ± 0.10
Arrowhead Test (Right) (s)	8.45 ± 0.29	8.28 ± 0.28
Arrowhead Test (Left) (s)	8.49 ± 0.29	8.39 ± 0.29
CMJ Test (cm)	36.66 ± 4.33	40.37 ± 4.92

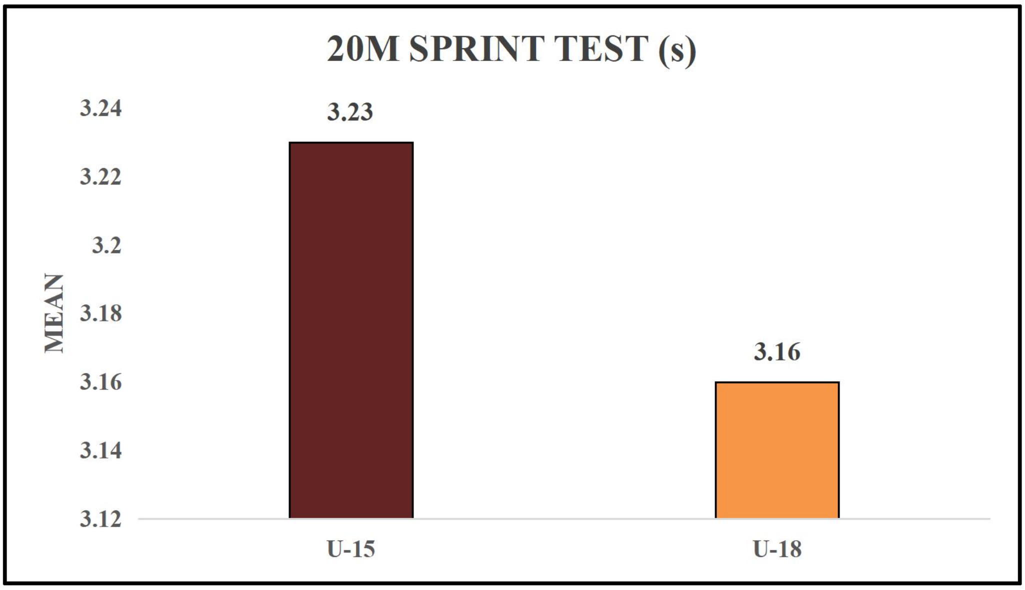

Figure 3.11 Descriptive Analysis for 20m Sprint Test between U-15 and U-18

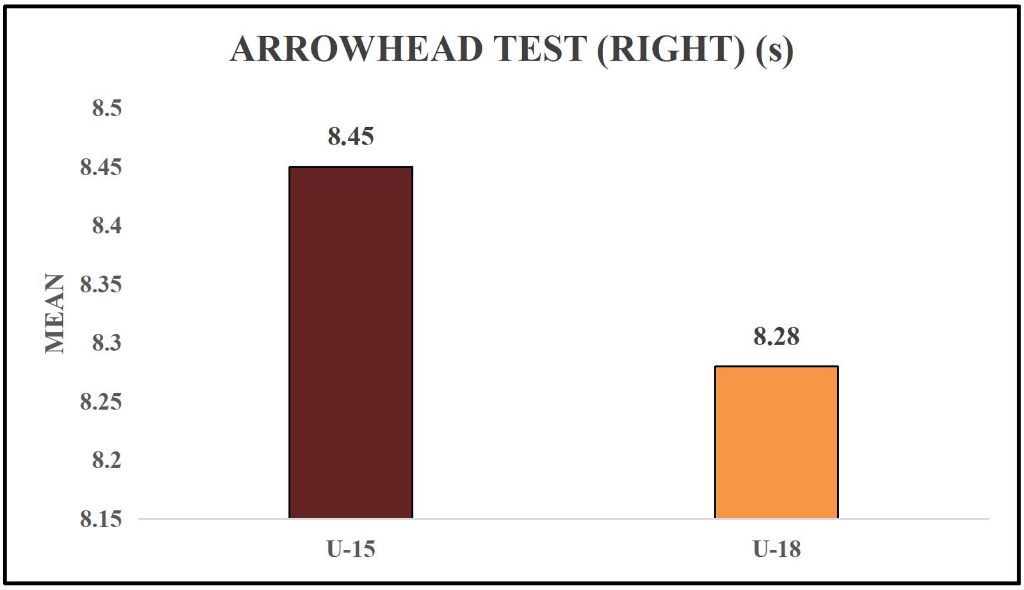

Figure 3.12 Descriptive Analysis for Arrowhead Test (Right) between U-15 and U-18

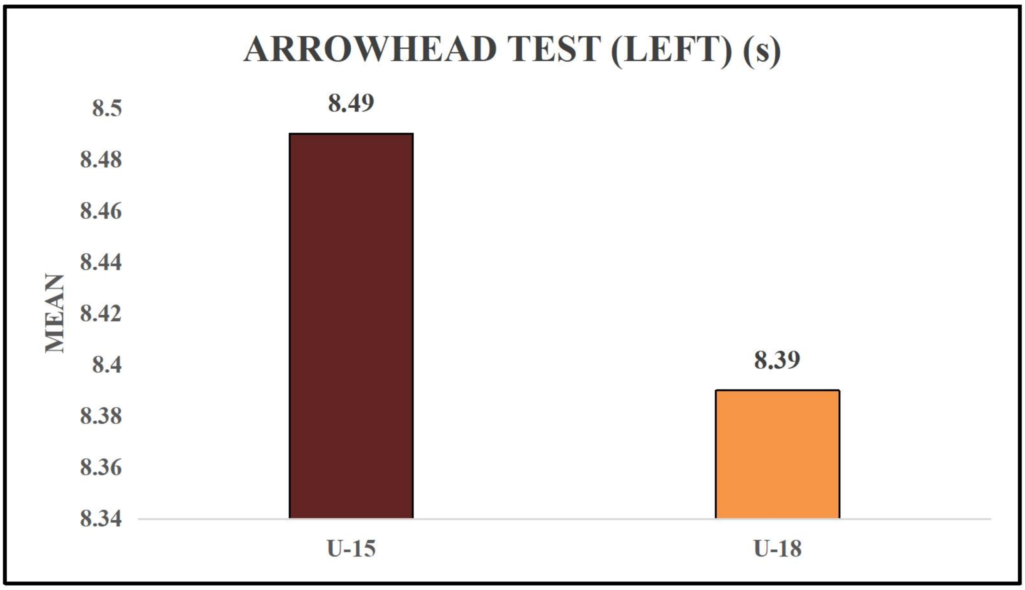

Figure 3.13 Descriptive Analysis for Arrowhead Test (Left) between U-15 and U-18

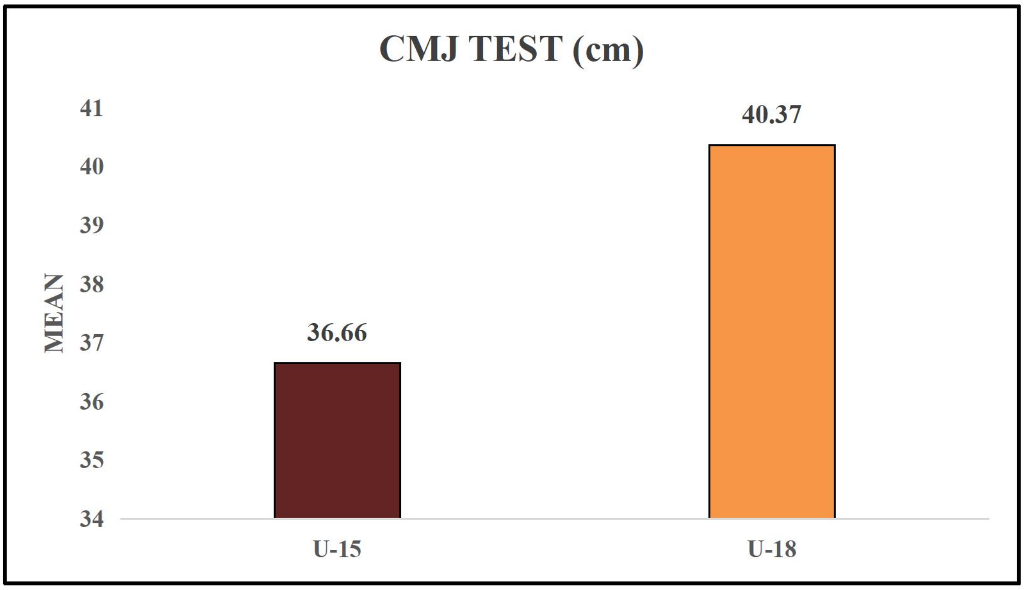

Figure 3.14 Descriptive Analysis for CMJ Test between U-15 and U-18

Table 3.11 presents the demoghraphic data of the participants and table 3.12 and Figure 3.11 to 3.14 presents the descriptive data of the participants in this study. The table illustrates the differences in mean and standard deviation (SD) values between U-15 and U-18 soccer players for each physical performance test.

3.6.2 Inferential Analysis

Table 3.3
Performance Test Comparison between U-15 and U-18.

	U-15	U-18			
	Mean ±SD	Mean ± SD	df	t	*p*-value
20m Sprint Test (s)	3.23 ± 0.09	3.16 ± 0.11	27.43	2.01	0.05*
Arrowhead Test (s) (Right)	8.45 ± 0.30	8.28 ± 0.29	27.98	1.51	0.14
Arrowhead Test (s) (Left)	8.49 ± 0.30	8.39 ± 0.30	28.00	0.95	0.35
CMJ Test (cm)	36.66 ± 4.48	40.37 ± 5.10	27.54	-2.12	0.04*

*Indicate significant difference, $p \leq 0.05$

Table 3.3 presents the results of the Independent T-test, comparing physical performance between U-15 and U-18 soccer players. A significant difference was observed in the explosive power performance (CMJ test, p = 0.04 leading to the rejection of the null hypothesis for this variable. In addition, speed performance results also shown statistical significance (p = 0.05), suggesting a potential age-related difference. However, no significant differences was found in change of direction (COD) performance, with results for the right and left Arrowhead Tests yielding p-values of 0.14 and 0.35, respectively. Consequently, the null hypothesis was accepted for COD performance, indicating no substantial differences between the two age groups in this aspect.

3.7 Discussion

This current study identified a significant difference in explosive power performance (CMJ test, p = 0.04) and a trend towards significance in speed performance (p = 0.05) between U-15 and U-18 soccer players. These findings suggest that difference in chronological age may contribute to variations in physical , as older players tend to develop superior muscle power and speed. This aligns with Béres et al., (2021), who reported that early-maturing youth soccer players exhibit higher physical fitness scores and may surpass their less mature counterparts at various selection stages. Growth and maturation are typically assessed using chronological and biological age (Ke et al., 2021). In this study, chronological age was used as a primary factor to assess performance differences, as it is a widely accepted measurement for age categorization in physical fitness standards globally (Ke et al., 2021). Previous studies have consistently demonstrated the impact of chronological age and its role in physical maturation, which subsequently influences performance outcomes (Lesinski et al., 2020; Giudicelli et al., 2021; Ke et al., 2021) . Older players generally mature earlier and possesses greater anthropometric qualities, contributing to enhanced sport-specific performance (Radnor et al., 2021). Age-related differences in growth and physical maturation influence performance in sport-specific tasks (Currie, 2018). This can be attributed to various physiological factors, including increased muscular strength, improved neuromuscular coordination, and refined motor skills. Furthermore, experience and tactical understanding accumulated over years of participation may enhance athletic performance during physical assessments. This notion is supported by Peitz et al. (2018), who highlighted neuromuscular changes during the transition from childhood to adulthood, including muscle-tendon development, improved muscle activation, increased androgen circulation, and enhanced motor unit recruitment. Furthermore, Pichardo et al. (2019) emphasized that such physiological transitions not only affect growth and development but also contribute to improvements in strength, sprinting, and jumping performance. Similarly, Kumar et al. (2021) indicated that these physiological adaptations significantly impact youth players' abilities to perform well in fitness tests.

As players mature, their maximal force production and muscle capabilities improve, particularly in the stretch-shortening cycle (SSC) and lower limb strength, which are crucial for jumping and sprinting (Kurihara et al., 2021). This is supported by França et al., (2021) chronological age is a strong predictor of explosive leg power from childhood to young adulthood, with performance increasing linearly from ages 5 to 18. The result are in line with Guimares et al. (2019), who examined the influence of age and maturity on physical and technical skill development in basketball players, finding that older and more mature athletes exhibited superior muscular strength, power and speed, leading to better jumping and sprinting performance. These attributes contribute to stronger force production and enhanced sprinting efficiency (Mancha-Triguero et al., 2021). Similarly, Pichardo et al., (2019) emphasized the role of strength in supporting movement competency in explosive actions like jumping and sprinting. In soccer-specific studies, significant differences in power performance and near-significant differences in sprinting ability have been reported between mature and younger players (Murtagh et al., 2020; Lesinski et al., 2020; Fernández-Galván et al., 2022). Yapici et al. (2022) further supported this, noting that muscle strength increases with age, with the most significant gains occurring during adolescence. These findings reinforce the notion that age, growth and maturation contribute to improved physical performance, which explains the superior results observed in the older players in the current study.

However, in contrast to power and speed, no significant differences were found in change of direction (COD) performance between U-15 and U-18 soccer players, COD ability involves reacting to external stimuli and pre-planning movement strategies (Pojskic et al., 2018). This finding is consistent with Fiorili et al., (2017), who found no significant difference in COD performance between U-16 and U-18 players. One possible explanation is that COD ability may develop independently of chronological age, as players refine specific agility-related skills regardless of their age group (Fiorili et al., 2017; Dugdale et al., 2020). Moreover, several factors influence COD performance such as technique, observation, perception, anticipation, decision making and biomechanical execution (Sariati et al., 2020; Sinkovic et al., 2023). Pojskic et al., (2018) highlighted that individual technical skills and movement efficiency significantly impact COD ability. Dugdale et al., (2020) further suggested that technical competency during COD assessments may account for performance variations. Furthermore, Sánchez-López et al., (2023) indicated that COD performance is more influenced by biomechanical factors such as braking force, ground contact time, pelvis alignment and foot placement rather than acceleration or linear speed. Although the COD tests used in this study have demonstrated validity and reliability for assessing soccer players' agility (Rago et al., 2020; Michailidis et al., 2021), additional studies is needed to explore COD performance in soccer-specific scenarios, particularly in dribbling situations (Pojskic et al., 2018).

3.7.1 Study Limitations and Future Directions

Several limitation of this study must be acknowledged. First, the study did not directly assess biological maturation (e.g., skeletal age, pubertal staging, or validated maturity-estimation methods); therefore, maturation was not analysed as a study variable.. While chronological age is commonly used to classify young athletes (Lesinski et al., 2020; Giudicelli et al., 2021), differences in maturity status may still affect physical testing outcomes (Pichardo et al., 2019). Future research should investigate the direct influence of biological maturity on speed and COD performance to provide a more precise understanding of developmental differences between age groups.

Second, this study did not include a structured training program for participants, which may have influenced individual performance levels. Silva (2022) emphasized that consistent training over several months can significantly impact physical performance. Therefore, future studies should examine age-related differences in performance after implementing a controlled training regime to assess longitudinal improvements.

Lastly, the relatively small sample size (n = 30) may have limited the statistical power of the study. Brysbaert (2019) suggested that larger sample sizes could yield more conclusive results and potentially uncover additional differences in speed, COD, and power performance between youth soccer players. Despite these limitations, the current study contributes valuable evidence supporting age-related differences in speed and power performance among youth soccer players.

3.8 Conclusion

Based on the findings, two significant results (Explosive power and speed) were found in this study and no significant difference was found in COD in relation to how age and maturity influence performance between the two age groups. Despite these mixed findings, the results have important practical implications, particularly for the ones involved in youth soccer. This study provides insights into the impact of chronological age on sport-related performance, which is influenced by the interplay of physical and physiological factors such as age, growth and maturation. Typically, earlier-maturing boys tend to be taller, heavier, and more muscular, which may contribute to their enhanced physical performance. However, these differences can be further shaped by targeted training interventions.

Given these findings, soccer coaches and trainers should develop tailored training programs that account for the diverse physical and physiological characteristics of young athletes. Individualizing the training process is crucial, as it allows coaches to address age-related variations in muscle maturity and performance potential. By applying these insights, coaches can create more effective training regimens that cater to the unique developmental needs of each player.

In summary, while growth and maturation variables were not directly assessed in this study, representing a key limitation, the findings still provide valuable practical applications for youth soccer development. This study highlights the nuanced relationship between age and sport performance, emphasizing the importance of recognizing and accommodating individual differences. By integrating age-specific training strategies, coaches can optimize player development and enhanced overall performance outcomes in youth soccer.

CHAPTER 4
IMPACT OF COMPLEX TRAINING ON SPEED, CHANGE OF DIRECTION, AND POWER PERFORMANCE IN U-15 AND U-18 SOCCER PLAYERS

4.1 Abstract

This study aimed to examine the effects of an 8-week complex training (CT) program on speed, change of direction (COD), and power performance in U-15 and U-18 soccer players and to determine whether age-related differences influence training adaptations. A total of 15 male soccer players were recruited from a secondary school and categorized into U-15 ($n = 8$, aged 13–15 years) and U-18 ($n = 7$, aged 16–18 years) groups. Participants underwent an 8-week CT program combining strength and plyometric exercises. Pre- and post-training assessments included the 20m Sprint Test (speed), Arrowhead Agility Test (COD), and Counter-Movement Jump (CMJ) Test (power). Wilcoxon Signed-Rank Test was used to evaluate within-group changes, while Mann-Whitney U Test compared differences between groups. Significant within-group improvements ($p \leq 0.05$) were observed in all tests for both age groups. In U-15 players, sprint time decreased ($Z = -2.59$, $p = 0.01$), agility improved ($Z = -2.53$ to -2.52, $p = 0.01$), and jump height increased ($Z = -2.52$, $p = 0.01$). Similar improvements were found in U-18 players ($Z = -2.38$ to -2.37, $p = 0.02$). However, between-group comparisons showed no significant differences in performance adaptations ($p > 0.05$). The results indicate that complex training effectively enhances speed, COD, and power performance in both U-15 and U-18 soccer players. However, age-related differences did not significantly influence training outcomes. These findings support the implementation of CT in youth soccer training, regardless of age category.

Keywords: youth soccer, athletic development, complex training, speed, change of direction, power

4.2 Introduction

Growth and biological maturation are defined as the status, tempo, timing and process of an individual from adolescence to maturity (Towlson et al, 2020). During growth and maturation, the neuromuscular system undergoes numerous natural changes, including alterations in muscle-tendon architecture, muscle activation, and an increase in circulating androgens as individuals progress from childhood to adolescence and eventually adulthood (Kumar et al., 2021). The puberty period plays a crucial role in the acquisition of skills and the enhancement of performance in young athletes. Suitable and appropriate training strategies during this period are essential to maintain good health, maximize sport-related performance and minimize the risk of injury (Campa and Greco, 2022). This study focuses on two specific age groups to examine the effects of Complex Training (CT). The rationale for selecting these age groups stems from a scarcity of research exploring changes in physical performance among different ages and maturity levels (Giudicelli et al., 2021; Fernández-Galván et al., 2022). This study highlights how chronological age typically serves as the primary measure for assessing an individual's growth and maturity (Ke et al., 2021).

Many past studies have indicated that chronological age has significant roles with physical maturation which may influence on physical performance (Lesinski et al., 2020; Giudicelli et al., 2021; Ke et al., 2021) . This is because older players tend to mature earlier and may possess greater anthropometric qualities and better sport performances (Radnor et al., 2021). Physically mature boys typically outperform less mature peers (Pichardo et al., 2019), however, limited studies exist to robustly support this observation (Zghal et al., 2019). This is supported by Soneeson et al., (2020) who stated that previous evidence has shown that performance of the youth athlete became plateaus after the age of 15 years old. To contribute more substantial evidence supporting differences in performance between different age groups, the current study seeks to investigate the differences in speed, change of direction and power performance among U-15 and U-18 soccer players. When engaging in training with youth athletes which in this case focusing on youth soccer players, suitable training program must be properly applied (Magallanes et al., 2022). It is essential to ensure that the program is not only effective in improving performance but also efficient while avoiding any physical harm or injuries. There have been many debates about suitable training programs for youth players because some past researcher have stated that they are injuries-prone due to immaturity of the skeletal system (Peitz et al., 2018). Thus, specific and appropriate training program must be implemented to gradually increase athletes' physical capabilities to maximize a young player's performance potential by the time they reach full maturity (Trecroci et al., 2020; Magallanes et al., 2022).

Different training methods have been proposed to properly increase youth soccer players capabilities to meet modern soccer demands which has undergone significant transformation becoming fast-paced and intermittent sport game (Michailidis et al., 2021; Yu et al., 2021; Andrašić et al., 2021) that consists of combination of short bursts of high-intensity activities, including sprinting, running, jumping, duels, tackling, and frequent changes of direction (COD), as well as periods of walking and standing (Pavillon et al., 2021; Gualtieri et al., 2023). Instead of applying traditional resistance training (RT) and plyometric training (PT) alone, complex training (CT) has been found to be one of appropriate method to improve overall development of youth athletes' physical abilities that has been successfully applied to various sports including soccer (Cavaco et al., 2014; Koval et al., 2016; Wang et al., 2023). CT is a training that combines both RT and PT in the same training program (Greenwood and Carter, 2014; Ali et al., 2019; Wang et al., 2023) which CT protocol alternates between heavy load RT, followed by biomechanically similar explosive PT exercises (Abdelkader, 2016; Ali et al., 2019; Wang et al., 2023). Many past studies have shown that combining both RT with PT in the same training program yields better outcomes in improving power and its' derivatives factors rather than RT and PT training separately (Zghal et al., 2019) which Ali et al., (2019) stated that CT could induced PT stimulus in enhancing explosive power and its' derivatives factors which current study highlighted three main physical components that crucial in soccer which are speed, change of direction (COD) and explosive power performance (Sonesson et al., 2020; Sariati et al., 2020; Keiner et al., 2021).

The aim of the current study was to investigate the differences in speed, change of direction (COD) and power performance between U-15 and U-18 soccer players after undergoing 8 weeks of CT program. Three physical tests were used to analyze the differences at the end of study which were the 20m sprint test, the arrowhead test, and the counter-movement jump test (CMJ). This study built upon Chapter 3, which examined performance differences between the two age groups but lacked a structured training intervention. To address this limitation, the researcher implemented a CT program to analyse its impact on performance and assess the differences between U-15 and U-18 players after systematic training. This approach was informed by Silva (2022), who highlighted that players' performance could vary significantly when engaged in consistent, structured training over time.

4.3 Method

4.3.1 Research Design

The research design for this study was a quasi-experimental Pre-test Post-test Design. The participants were divided into two groups: U-15 (n=8) and U-18 (n=7), both of which underwent an 8-week CT program. The pre-test data collection procedures were the same as those described in Chapter 3, with the data from Chapter 3 serving as the pre-test data for this study.

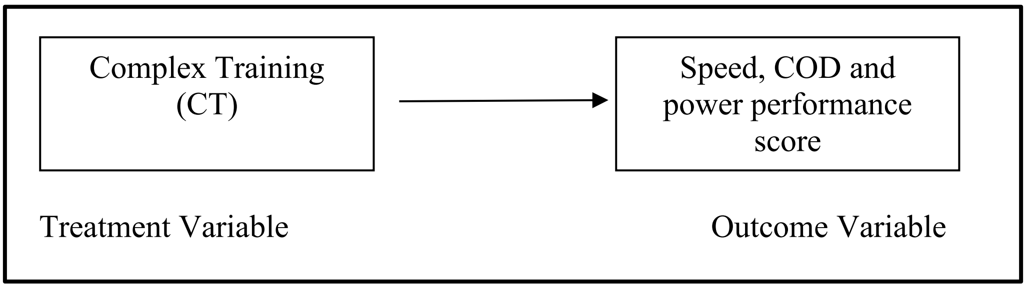

Figure 4.1 Conceptual Framework

4.3.2 Population/ Sample/Participants/Sampling Technique

The participants in this second study consisted of 15 soccer players (n=15) from Sultan Idris Shah II Secondary School, Malaysia. They were divided into two age groups: Under-15 (n=8; aged 13-15 years) and Under-18 (n=7; aged 16-18 years). The descriptive statistics for each group were as follows: U-15 (n=8): Age = 14.50 ± 0.71 years, Height = 163.00 ± 4.69 cm, Body Mass = 51.05 ± 6.59 kg; U-18 (n=7): Age = 16.29 ± 0.45 years, Height = 167.93 ± 0.03 cm, Body Mass = 56.19 ± 4.85 kg.

4.3.3 Instrument and Instrumentation

4.3.3.1 Instrument

a) Gym Equipment

The gym equipment was used for resistance training (RT). All equipment was sourced from Sekolah Menengah Sultan Idris Shah II's gymnasium. The equipment included an Olympic bar, dumbbells, weight plates and assisted machines such as the leg extension machine and leg press machine.

b) Plyometric Equipment

The plyometric equipment was used for plyometric training. All equipment was obtained from Sekolah Menengah Sultan Idris Shah II's gymnasium. The equipment included boxes and hurdles, with heights ranging from 20cm to 60cm.

4.3.3.2 Instrumentation

a) Pre-Test

The pre-test protocols used were the same as those in Chapter 3, including the data for anthropometric measurements and assessments. The assessments conducted included the 20m sprint test, arrowhead test and counter-movement jump test (CMJ).

b) Complex Training (CT) Program

The One week after the pre-test, both U-15 and U-18 groups participated in three training sessions per week. These sessions consisted of various CT training exercises conducted by the researcher. The results after 8 weeks of CT program will determine the effectiveness of CT between the two age groups.

The training was adapted and adopted from Abdelkader (2016). The CT training was applied during the specific preparation phase, as shown in Figure 4.1. The resistance training (RT) involved the use of dumbbells, barbells and Olympic bar, focusing on the lower extremities (2 sets of 3-8 repetitions, with a range of 70-95% of

1RM). The plyometric training involved the use of boxes and hurdles, with the height ranging from 20-60cm. The plyometric training was done after the RT and included 2 sets of 6-10 repetitions of plyometric jumps in the same session. The rest interval ranged from 2-3 minutes. The training was done before soccer team training and after they were done with the training, they will join the team training. The CT alternated with the rest day (No CT done in that day). The training day mostly done on Monday, Wednesday and Friday but sometimes changed to Tuesday, Thursday and Saturday if the team has one day off during that week. The training program is outlined in Table 4.1.

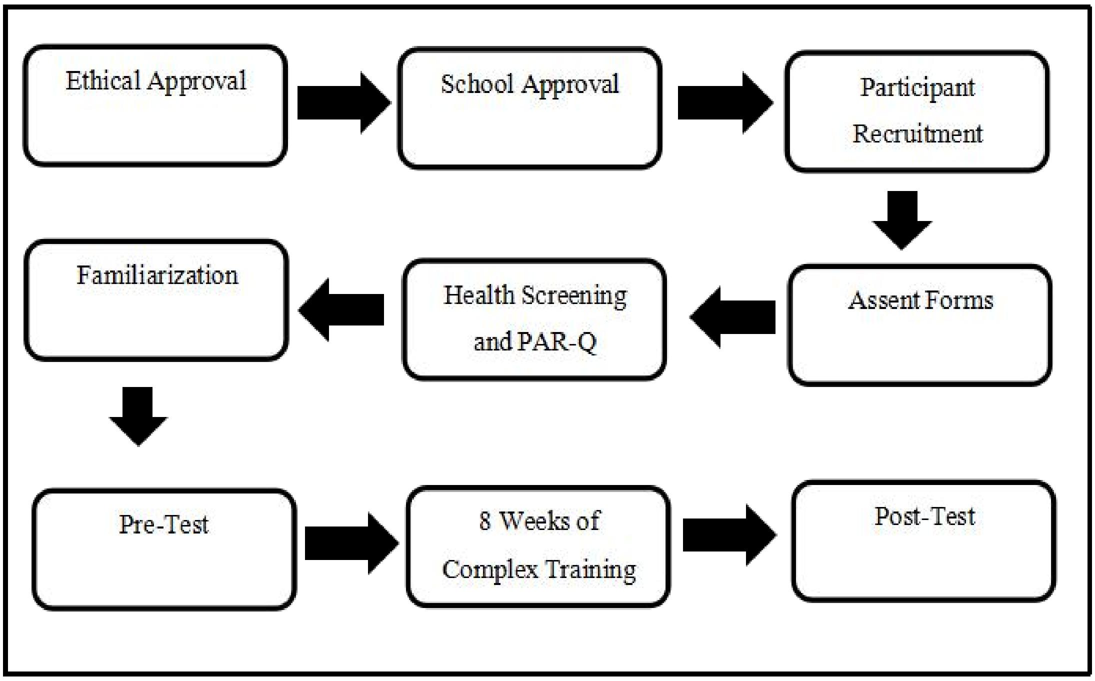

Figure 4.2 Research Flow Chart

Table 4.1
CT Training Program

Day/Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0	No Training	No Training	No Training	No Training	No Training	No Training	Pre-Test
1	2x8 Olympic Bar Back Squat (70% 1RM) 2x6 Alternate Lunge Jump	Soccer Team Training	2x8 Dumbbell Standing Calf Raise at 70% 1RM 2x8 Depth Jump 40cm	Soccer Team Training	2x8 Leg Extension at 70% 1RM 2x8 Drop Jump at 40cm	Rest Day/ No Training	Rest Day/ No Training
2	2x8 Single Leg Dumbbell Lunge at 70% 1RM 2x8 Alternate Lunge Jump	Soccer Team Training	2x8 Dumbbell Single Leg Standing Calf Raise at 70% 1RM 2x8 Single Leg Depth Jumps 20cm Box	Soccer Team Training	2x8 Leg Curl at 70% 1RM 2x8 Single Leg Hurdle Jumps 30cm (4 Hurdles)	Rest Day/ No Training	Rest Day/ No Training
3	2x8 Leg Press at 70% 1RM 2x10 Box Jump (50cm)	Soccer Team Training	2x6 Barbell Split Squat at 80% 1RM 2x10 Split Squat Jump	Soccer Team Training	2x6 Barbell Box Step Up at 80% 1RM (40cm Box) 2x8 Box Step Up Jump	Rest Day/ No Training	Rest Day/ No Training
4	1x6 Olympic Bar Back Squat at 80% 1RM 1x8 Vertical Hurdle Jump (4Hurdles) 1x6 Dumbbell Single Leg Lunge at 80% 1RM 1x8 Alternate	1x6 Dumbbell Standing Calf Raise at 80% 1RM 1x10 Depth Jumps to Second Box (40cm) 1x5 Olympic Bar Split Squat at 85% 1RM 1x5 Split Squat	Soccer Team Training	1x6 Leg Extension at 80% 1RM 1x10 Box Jump at 40cm 1x6 Leg Curl at 80% 1RM 1x10 Vertical Side Hurdle Jumps 40cm (4Hurdles)	Soccer Team Training	Light Training/ Recovery	Rest Day/ No Training

Day/Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Lunge Jump	Jumps followed by 5 Vertical Hurdles Jumps (40cm)					
5	Soccer Team Training/Light Training/ Recovery	1x8 Leg Press at 70% 1RM 1x8 Box Jump (50cm) then Depth Jumps to Second Box 40cm 1x6 Barbell Single Leg Lunge at 80% 1RM 1x10 Alternate Lunge Jump	Soccer Team Training	1x5 Dumbbell Calf Raise at 85% 1RM 1x8 Side Depth Jump 50cm Followed by Side Jumping Over 4 Hurdles 40cm 1x6 Leg Curl at 80% 1RM 1x6 Vertical Counter-Movement Jumps Followed by Forward Jump	Soccer Team Training	1x5 Olympic Bar Box Step Up at 85% 1RM (40cm Box) 1x8 Step Up Jumps 1x5 Leg Extension at 85% 1RM 1x8 Single Leg Side Hurdle Jumps 40cm (4Hurdles) followed by Forward Jump	Rest Day/ No Training
6	1x5 Olympic Bar Split Squat at 85% 1RM 1x8 Box Jump then 2 Vertical Hurdle Jumps 1x4 Olympic Bar Standing Calf Raise at 90% 1RM 1x10 Depth Jumps to Second Box 40cm then 3 Vertical Hurdle Jumps	Soccer Team Training	1x4 Olympic Bar Squat at 90% 1RM 1x8 Backward Depth Jump 45cm 1x6 Leg Press at 90% 1RM 1x10 Box Jump (50cm) to Depth Jumps then 2 Hurdle Vertical Jumps	Soccer Team Training	1x4 Olympic Bar Box Step Up at 90% 1RM (40cm Box) 1x8 Step Up Jumps 1x4 Olympic Bar Standing Calf Raise at 90% 1RM 2x10 Side Depth Jump Followed by 3 Hurdles Jumps	Rest day/ No Training	Rest Day/ No Training
7	1x4 Leg Extension at 90% 1RM 1x8 Depth Jump to	Soccer Team Training	1x4 Leg Press a 90% 1RM 1x6 Box Jump	Soccer Team Training	1x4 Olympic Bar Back Squat at 90% 1RM	Rest Day/ No Training	Rest Day/ No Training

Day/Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Second Box to Drop Jump 40cm 1x4 Leg Curl at 90% 1RM 1x6 Single Leg Hurdle Jump 30cm (4Hurdles)		(60cm) then Depth Jump to Second Box 40cm 1x4 Leg Extension at 90% 1RM 1x10 Box jump 40cm to Drop Jump		1x6 Squat Jump Followed by 2 Vertical Hurdle Jumps (40cm) then 2 Side Vertical Hurdle Jumps 1x4 Olympic Bar Split Squat at 90% 1RM 1x4 Vertical Hurdle Jump (4Hurdles) then Box Jump (40cm) to Depth Jump to Vertical Jump		
8	1x3 Olympic Bar Standing Calf Raise at 95% 1RM 1x6 Depth Jumps to Second Box 40cm 1x3 Olympic Bar Single Leg Lunge at 95% 1RM 1x6 Alternating Lunge Jump then Box Jump to Depth Jump	1x3 Olympic Bar Box Step Up at 95% 1RM (40cm Box) 1x8 Step up Jump 1x3 Back Squat at 95% 1RM 1x4 Vertical Hurdle Jump (4Hurdles) then Box Jump (40cm) to Depth Jump to Vertical Jump	Soccer Team Training	1x3 Leg Curl at 95% 1RM 1x6 Single Leg Hurdle Jump 30cm (4Hurdles) 1x3 Split Squat at 95% 1RM 1x8 Split Squat Jump then 2 Vertical Hurdle Jumps then Vertical Jump	Soccer Team Training	Light Training/ Recovery	Post-Test 2

4.4 Data Collection

The current study used the same procedures from Chapter 3 for the health screening and assent forms, which were signed by the participants' parents or guardians. The study also followed the same data collection protocols for the assessments as described in Chapter 3, where all the data collected in Chapter 3 were used as pre-test data for the current study.

As stated, the current study began a week after previous study was completed (as shown in Figure 4.1). The participants were then divided into two groups: U-15 (n=15) and U-18 (n=18). They participated in a CT training program three times per week for a total duration of eight weeks. The training was adapted and adopted from Abdelkader (2016). The CT training was applied during the specific preparation phase, as shown in Figure 4.1 which the training involved resistance training (RT) focusing on the lower extremities (2 sets of 3-8 repetitions, with a range of 70-95% of 1RM) followed by plyometric training (PT) that been done after the RT and included 2 sets of 6-10 repetitions of plyometric jumps in the same session. The rest interval ranged from 2-3 minutes. The training continued for the whole 8 weeks. In the 8th week (Sunday), the participants underwent post-test. The data from the post-test were collected and analysed.

4.4.1 Post-Testing Control Procedures

Post-testing was conducted 48–72 hours after the final training session to minimise the potential influence of residual fatigue. Participants were instructed to avoid additional strenuous physical activity during this recovery period. The post-test assessments were performed under conditions consistent with the pre-test, including standardized warm-up procedures, similar time of day, and identical testing protocols. These procedures were implemented to ensure that performance outcomes reflected training adaptations rather than acute fatigue effects.

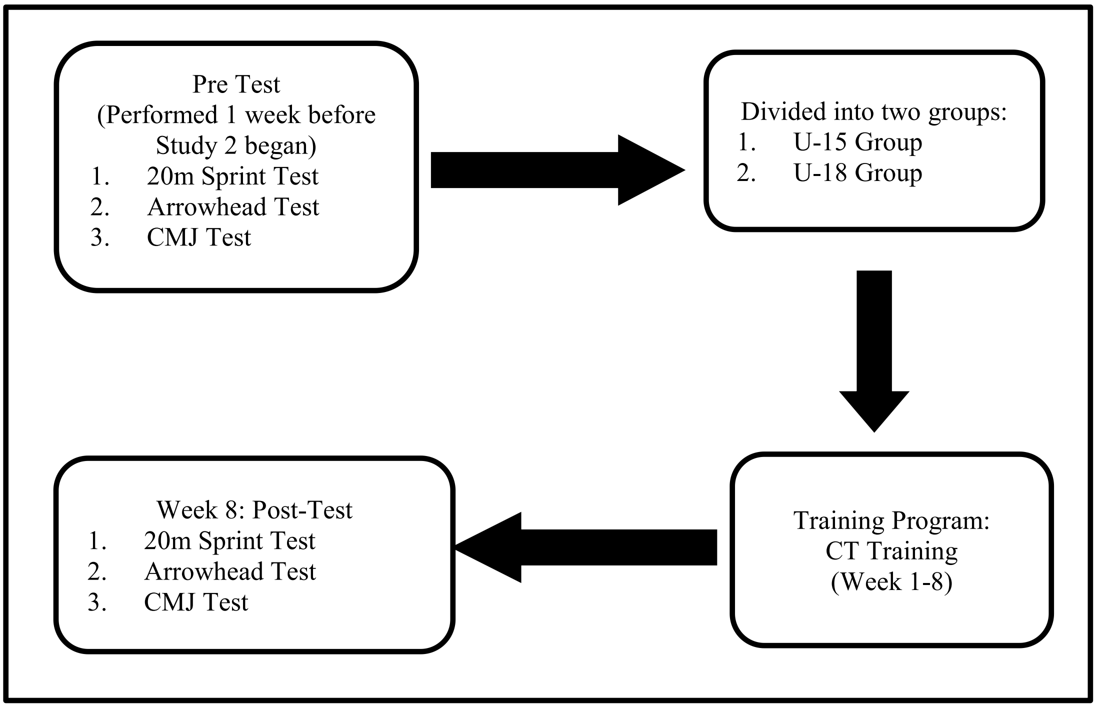

Figure 4.3 Data Collection Procedures

4.5 Data Analysis

To interpret the data for this study, the Statistical Package for Social Science (IBM SPSS Version 25) was used. The data obtained from both pre-test and post-test data of 20m sprint test, Arrowhead test and Counter-Movement Jump (CMJ) test were presented in a descriptive analysis as mean and standard deviation (SD) to analyse the effects of CT before and after undergoing 8 weeks of training.

A non-parametric analysis, the Wilcoxon Signed Rank Test was used to investigate the effects of eight weeks of complex training on speed, change of direction (COD) and power performance in the U-15 and U-18 groups. To compare the differences between the two groups, the Mann-Whitney Test was used.

4.6 Result

4.6.1 Descriptive Statistics

Table 4.2
Demographic Comparison between U-15 and U-18.

Variables	U-15 (n=8) Mean ± SD	U-18 (n=7) Mean ± SD
Age (years)	14.50 ± 0.71	16.29 ± 0.45
Weight (kg)	51.05 ± 6.59	56.19 ±4.85
Height (cm)	163.00 ± 4.69	167.93 ±2.86

Table 4.2 shown above presents the demographic data of the participants in this study. There were four variables observed: age (years), weight (kg), height (m) and mean-standard deviation scores of the participants. There were 15 participants in this study (n = 15) with the U-15 group consisting of 8 players (n=8) and the U-18 group consisting of 7 players (n=7).

Table 4.3
Descriptive Analysis of Pre and Post Test between U-15 and U-18 Soccer Players

Variables	U-15 (n=8)		U-18 (n=7)	
	Pre-Test Mean ± SD	Post-Test Mean ± SD	Pre-Test Mean ± SD	Post-Test Mean ± SD
20m Sprint Test (s)	3.24 ± 0.05	3.20 ± 0.04	3.15 ± 0.12	3.08 ± 0.11
Arrowhead Test (Right) (s)	8.38 ± 0.23	8.18 ± 0.10	8.23 ± 0.25	8.1 ± 0.21
Arrowhead Test (Left) (s)	8.45 ± 0.24	8.27 ± 0.20	8.28 ± 0.24	8.22 ± 0.24
CMJ Test (cm)	35.42 ± 4.24	40.65 ± 2.83	40.25 ± 6.06	44.52 ± 5.99

Table 4.3 shown above is a descriptive analysis for the pre and post-test of both groups in this study. The data in the table then presented in Figure 4.4 to 4.11.

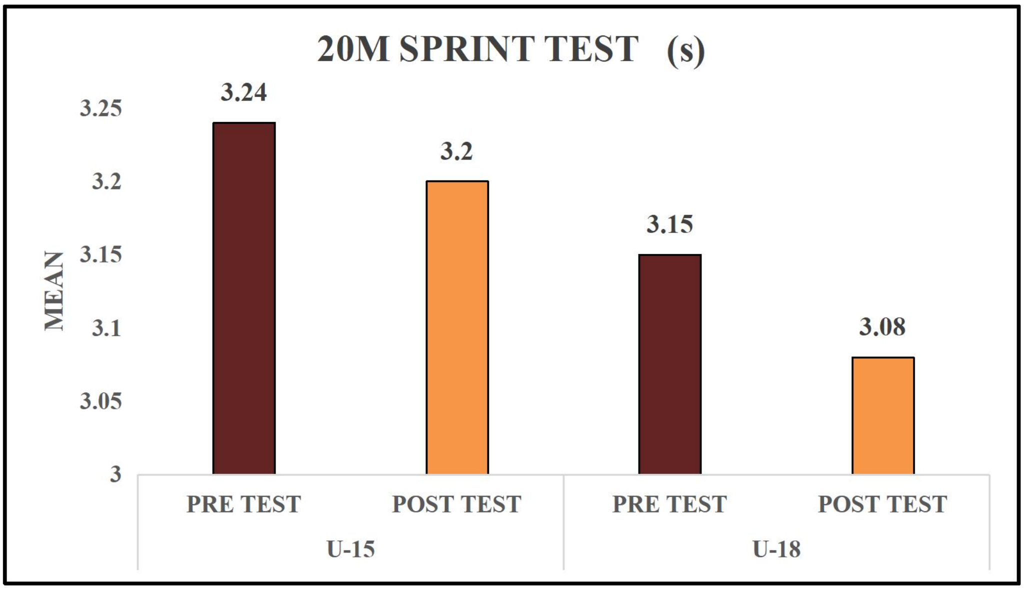

Figure 4.4 Performance Changes after 8 Weeks of CT across Age Group in 20m Sprint Test

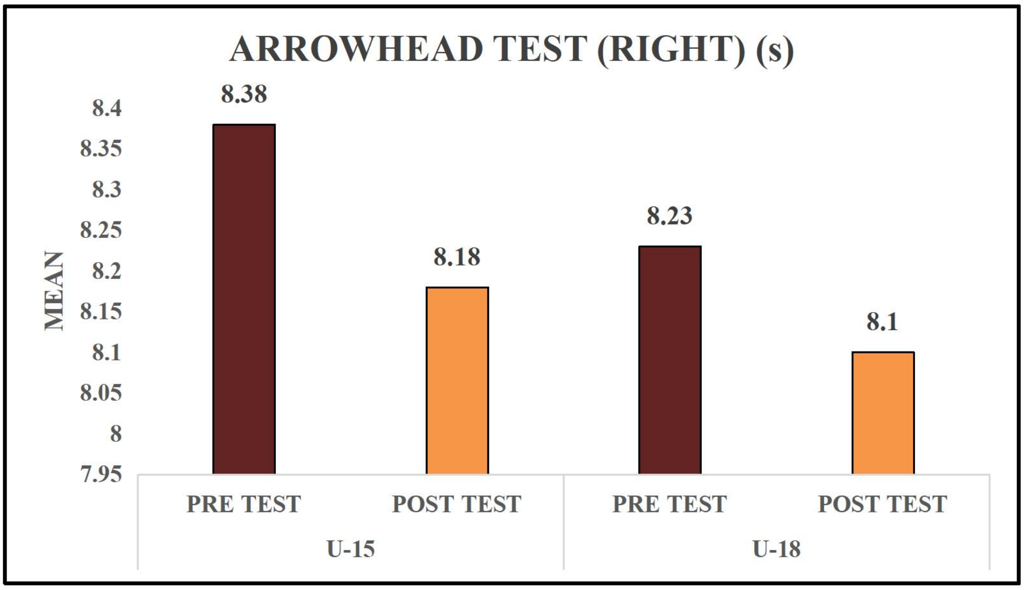

Figure 4.5 Performance Changes after 8 Weeks of CT across Age Group in Arrowhead Test (Right)

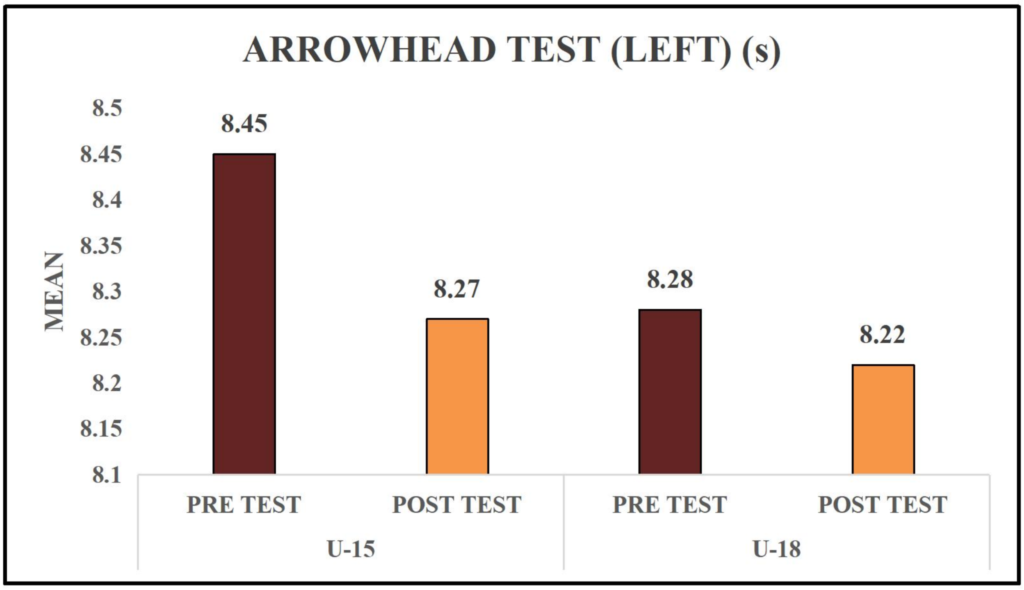

Figure 4.6 Performance Changes after 8 Weeks of CT across Age Group in Arrowhead Test (Left)

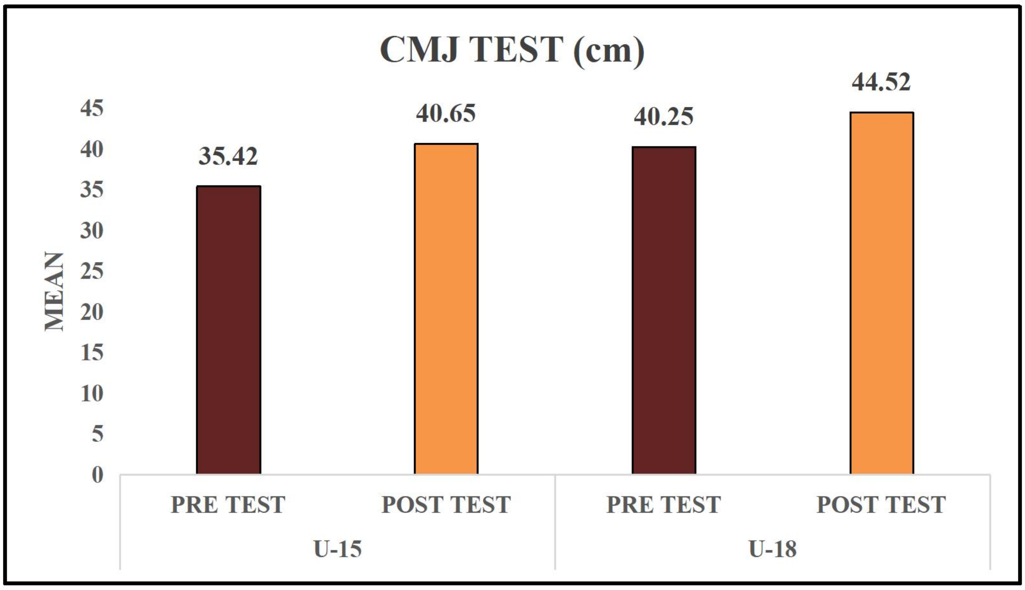

Figure 4.7 Performance Changes after 8 Weeks of CT across Age Group in CMJ Test

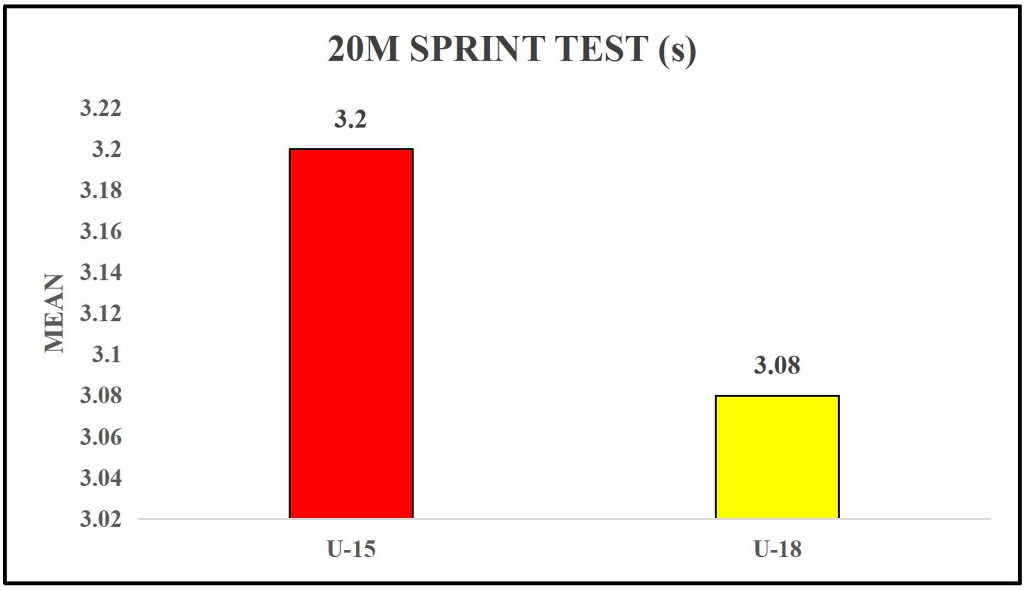

Figure 4.8 Performance Comparison after 8 Weeks of CT across Age Groups in 20m Sprint Test

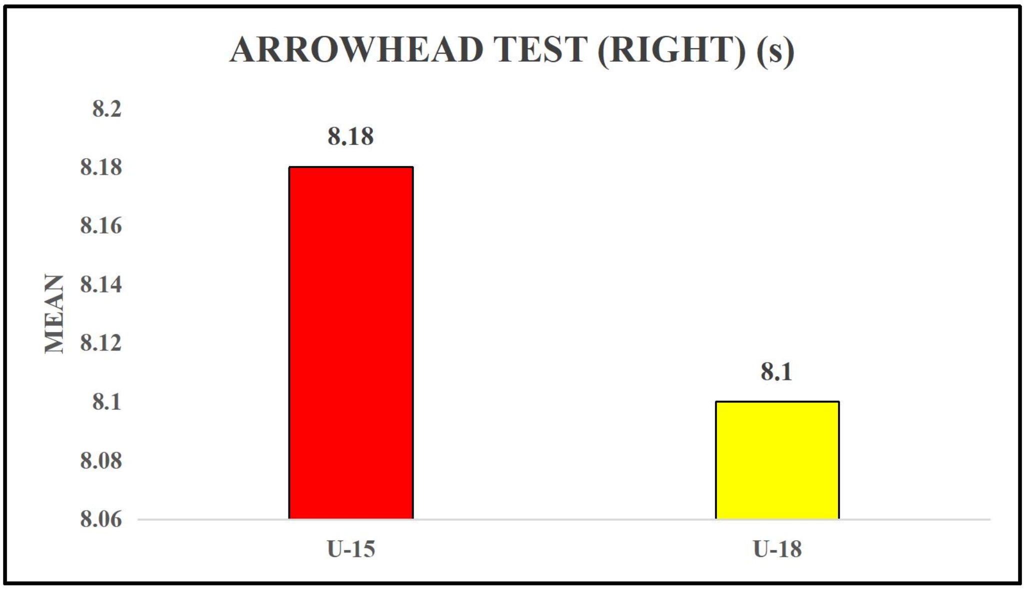

Figure 4.9 Performance Comparison after 8 Weeks of CT across Age Groups in Arrowhead Test (Right)

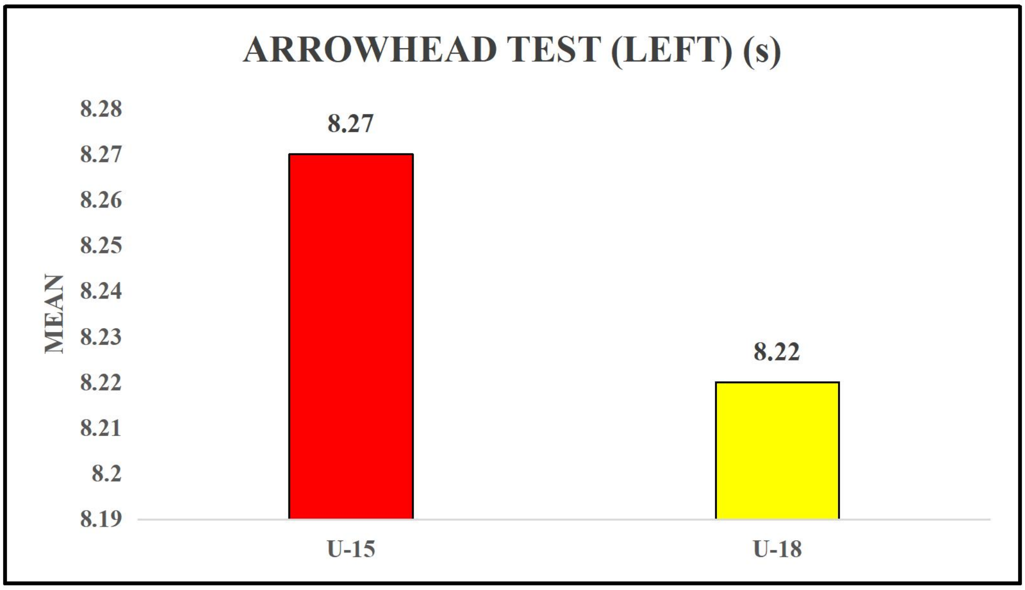

Figure 4.10 Performance Comparison after 8 Weeks of CT across Age Groups in Arrowhead Test (Left)

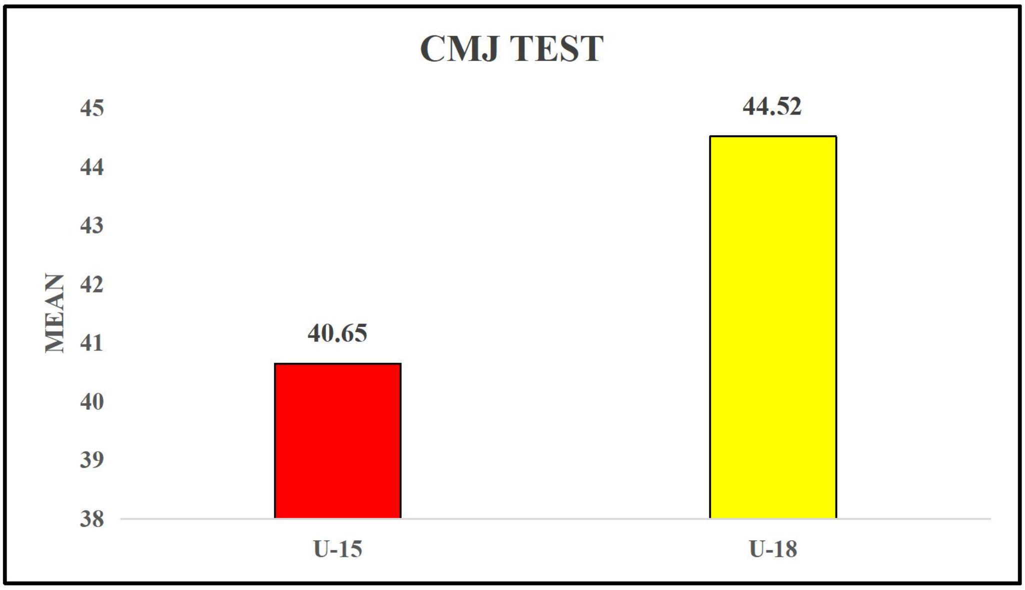

Figure 4.11 Performance Comparison after 8 Weeks of CT across Age Groups in CMJ Test

4.6.2 Inferential Analysis

Table 4.4
Effects of Complex Training (CT) on Speed, Change of Direction (COD) and Power Performance in U-15

	Pre-Test		Post-Test		Wilcoxon Signed Rank Test Probability	
	Mean ± SD	Median	Mean ± SD	Median	Z-value	p-value
20m Sprint Test (s)	3.24 ± 0.05	3.24	3.20 ± 0.05	3.20	2.59	0.01*
Arrowhead Test (Right) (s)	8.38 ± 0.25	8.32	8.18 ± 0.11	8.22	2.53	0.01*
Arrowhead Test (Left) (s)	8.45 ± 0.25	8.42	8.27 ± 0.21	8.24	2.52	0.01*
CMJ Test (cm)	35.42 ± 4.53	35.16	40.65 ± 3.02	41.13	-2.52	0.01*

*Indicates significant difference , p≤0.05

Table 4.5
Effects of Complex Training (CT) on Speed, Change of Direction (COD) and Power Performance in U-18

	Pre-Test		Post-Test		Wilcoxon Signed Rank Test Probability	
	Mean ± SD	Median	Mean ± SD	Median	Z-value	p-value
20m Sprint Test (s)	3.15 ± 0.13	3.10	3.08 ± 0.12	3.04	2.38	0.02*
Arrowhead Test (Right) (s)	8.23 ± 0.27	8.13	8.10 ± 0.22	8.10	2.37	0.02*
Arrowhead Test (Left) (s)	8.28 ± 0.25	8.18	8.22 ± 0.25	8.16	2.37	0.02*
CMJ Test (cm)	40.25 ± 6.54	38.80	44.52 ± 6.47	44.12	2.37	0.02*

*Indicate significant difference , $p \leq 0.05$

Table 4.4 presents the effects of an eight-week Complex Training (CT) program on speed, change of direction (COD), and power performance in U-15 participants. The Wilcoxon Signed Rank Test results indicate significant improvements across all tested parameters ($p = 0.01$). Specifically, the 20m Sprint Test showed a decrease in time from 3.24 ± 0.05s to 3.20 ± 0.05s, indicating improved sprint speed. Both Arrowhead Tests (Right and Left) demonstrated faster times, with the right side improving from 8.38 ± 0.25s to 8.18 ± 0.11s and the left side from 8.45 ± 0.25s to 8.27 ± 0.21s, reflecting enhanced agility and COD ability. Additionally, counter-movement jump (CMJ) performance significantly increased from 35.42 ± 4.53 cm to 40.65 ± 3.02 cm, suggesting improved lower-body power. Overall, the findings highlight the positive impact of CT on speed, agility, and power in U-15 athletes, with all improvements reaching statistical significance ($p \leq 0.05$).

As for U-18, Table 4.5 illustrates the effects of an eight-week Complex Training (CT) program on speed, change of direction (COD), and power performance in U-18 participants. The Wilcoxon Signed Rank Test results indicate significant improvements across all tested parameters ($p = 0.02$).The 20m Sprint Test showed a reduction in sprint time from 3.15 ± 0.13s to 3.08 ± 0.12s, indicating enhanced speed. The Arrowhead Test (Right) improved from 8.23 ± 0.27s to 8.10 ± 0.22s, while the Arrowhead Test (Left) improved from 8.28 ± 0.25s to 8.22 ± 0.25s, reflecting better agility and COD ability. Additionally, counter-movement jump (CMJ) performance significantly increased from 40.25 ± 6.54 cm to 44.52 ± 6.47 cm, suggesting greater lower-body power. Overall, the findings demonstrate that CT positively influences speed, agility, and power in U-18 athletes, with all improvements reaching statistical significance ($p \leq 0.05$).

Table 4.6
Differences of Performance between CT and Control Group after 8 weeks.

	U-15 (n=8)	U-18 (n=7)	Mann-Whitney U Test			
	Mean Rank	Mean Rank	Mean ± SD	U	Z-value	p-value
20m Sprint Test (s)	10.06	5.64	3.15 ± 0.10	11.50	-1.92	0.06
Arrowhead Test (Right) (s)	9.13	6.71	8.14 ± 0.17	19.00	-1.04	0.30
Arrowhead Test (Left) (s)	8.88	7.00	8.25 ± 0.22	21.00	-0.81	0.42
CMJ Test (cm)	6.88	9.29	42.45 ± 5.15	19.00	-1.04	0.30

*Indicate significant difference, $p \leq 0.05$

The Mann-Whitney U Test was conducted to compare the performance differences between the U-15 (n=8) and U-18 (n=7) groups across four physical performance tests: the 20m Sprint Test, Arrowhead Test (Right and Left), and the Counter-Movement Jump (CMJ) Test. The results showed that there were no statistically significant differences between the groups in any of the tests. The U-15 group had higher mean ranks than the U-18 group in the 20m Sprint test (10.06 vs. 5.64), while the U-18 group had higher mean ranks in the CMJ Test (9.29 vs. 6.88), but these differences were not significant ($U = 11.50$, $Z = -1.92$, $p = 0.06$ for the Sprint, $U = 19.00$, $Z = -1.04$, $p = 0.30$ for the Arrowhead tests, and $U = 19.00$, $Z = -1.04$, $p = 0.30$ for the CMJ). Similarly, performance in both the Right and Left Arrowhead Tests was comparable between the two groups, with no significant differences ($p = 0.30$ and $p = 0.42$ respectively). These findings suggest that, despite slight differences in ranks, the U-15 and U-18 groups exhibited similar performance across sprint, change of direction, and jump power tests.

4.7 Discussion

4.7.1 Effects of Complex Training (CT) on Speed, Change of Direction (COD) and Power Performance in U-15 and U-18

The findings of this study revealed both the U-15 and U-18 groups showed significant improvements after undergoing an 8-week complex training (CT) program.

CT has been widely recognised in the literature for enhancing lower body power (Lim & Barley, 2016), an is especially relevant for soccer, where high-intensity, explosive movements such as sprinting, change of direction (COD), and jumping are crucial for performance (Freitas et al., 2017). The improvements observed in the current study can be explained by three primary physiological mechanisms: Post-Activation Potentiation (PAP), physiological changes, and hormonal and cellular adaptations.

i. Post-Activation Potentiation (PAP)

One key mechanism for improvement is the CT-induced PAP response of the muscles. PAP refers to the neuro-muscular condition in skeletal muscles following a bout of heavy resistance exercise (Lim & Barley, 2016). PAP enhances the rate of force development, resulting in increased acceleration and velocity in the muscles during movement execution, leading to both acute and long-term improvements in strength and power (Lim & Barley, 2016). The combination of resistance training (RT) and plyometric training (PT) enhances the PAP response, particularly in athletes, by recruiting a higher percentage of type IIx muscle fibers (Gołaś et al., 2016). This increased recruitment of type IIx fibers improves contraction velocity, explosive power production, and force development, contributing to greater athletic performance in short-duration, high-intensity movements (Thapa et al., 2020). Furthermore, CT improves motor unit coordination and activation, enhancing performance in movements such as jumping (Jusoh et al., 2019).

In soccer where high-intensity, explosive movements such as sprinting, change of direction (COD) and jumping are essential, CT could be used to enhance performance capabilities (Freitas et al., 2017). These results can be explained by three primary physiological mechanisms: Post-Activation Potentiation (PAP), morphological changes, and hormonal and cellular adaptations that occur in response to training. Baumgart et al. (2018) further support these findings, suggesting that natural growth processes, including hormonal changes like elevated testosterone levels, alongside training-induced modifications such as increased muscle mass and better neural control which contribute significantly to enhanced force and power generation.

ii. Physiological Changes

Another significant factor in the improvements observed could be the physiological changes induced by CT. The combination of RT and PT enhances muscle hypertrophy, neuromuscular efficiency, and reactive strength, which collectively lead to better performance in sport-specific movements (Schneiker et al., 2023). Previous studies have shown that CT promotes muscle hyperthrophy and an increase in muscle cross-sectional area, which contributes to greater force production and enhanced power, particularly in explosive movements (Grgic et al., 2021). The current study aligns with this findings, showing that CT effectively increases muscle size and cross-sectional areas, leading to improved muscle power and speed.

iii. Hormonal Adaptations

Although no direct measurements of testosterone were taken in this study, the hormonal response to CT likely played a role in the observed improvements. Previous studies have shown that RT combined with PT can elevate testosterone levels, which in turn may improve muscle mass, strength, and power (Greenwood & Carter, 2014; Vanny & Moon, 2015). This hormonal increase contributes to enhanced muscle strength, power and endurance, ultimately improving athletic performance (Ali et al., 2019; Zouhal et al., 2022). These hormonal adaptations help support various ergogenic, anabolic, and anti-catabolic functions in skeletal muscle, boosting overall athletic capabilities.

4.7.2 Differences between the U-15 and U-18 in Speed, Change of Direction (COD) and Power Performance after 8 Weeks of Intervention.

i. Importance of Speed, COD and Power in Soccer

Modern soccer is characterized by short-duration, high intensity activities that require a combination of three key physical abilities: speed, change of direction (COD) and power (Pavillon et al., 2021; Gualtieri et al., 2023). The significance of possessing good speed, change of direction and explosive power is not only important for individual players but also has a substantial impact on team performance, both in adult and youth soccer (Zghal et al., 2019; Andrašić et al., 2021). Previous studies suggest that mature players tend to exhibit better sport-related performance (Radnor et al., 2017; Radnor et al., 2021). However, in contrast to these findings, the current study found no significant differences in speed, COD, and power performance between the U-15 and U-18 groups. Several factors could explain this result, including biomechanical efficiency and technical adaptation due to training.

ii. Biomechanical Efficiency and Training Adaptation

Biomechanical efficiency and technical adaptations from training could have contributed to the lack of significant differences between the U-15 and U-18 groups. Training-induced adaptations improve the neuromuscular system's ability to produce rapid force and enhance the mechanisms of the stretch-shortening cycle (SSC). This results in improved SSC function during movements such as sprinting or agility-related tasks (Radnor et al., 2017). After the 8-week CT program, improvements in SSC function were observed in both groups. However, the specific mechanisms underlying these improvements remain unclear, and further research is needed to better understand the structural and neural adaptations resulting from the training (Radnor et al., 2017).

iii. Technical Adaptations

Both groups underwent CT combined with soccer-specific training that involved physical, technical and tactical components, which likely contributed to their performance improvements. These adaptations, such as better sprinting technique, step length, reduced contact time during acceleration, improved lower limb strength, and enhanced body coordination, may have influenced the results observed in speed performance (Pavillon et al., 2020; Silva et al., 2022). Hammami et al. (2018) supported this idea by stating that athletes' training status and technical factors during testing may significantly affect the results. It is possible that during the 8-week CT program, combined with normal soccer training, the players developed more effective techniques and experienced favourable psychological or hormonal influences, contributing to their performance during testing (Cavaco et al., 2014; Pojskic et al., 2018; Silva et al., 2022).

iv. Strength and Power Development

The development of strength and power resulting from CT training is influenced by biological, physiological, and neurological factors. Growth and maturation lead morphological changes such as increased of muscle size, fascicle length, pennation angle, and cross-sectional areas of muscles and tendons. These changes, along with enhanced tendon stiffness, contribute to improved muscle recruitment, pre-activation, reflex control, and reduced co-contraction (Baumgart et al., 2018; Sarkar & Bhattacharya, 2024). Training enhances the stretch-shortening function, allowing athletes to perform exercises more effectively with higher levels of eccentric strain on their muscles (Sarkar & Bhattacharya, 2024). Radnor et al. (2017) also noted that muscle hypertrophy, particularly in lower limb muscles, is a key predictor of maximum strength and power, which contributes to better performance in SSC activities like sprinting. Baumgart et al. (2018) further confirmed that tendon size increases in relation to the functional and morphological development of muscles, enhancing force production during sprinting.

v. Non-Significant COD Performance Differences

The current study found no significant differences in COD performance between the two groups. This result is consistent with a study by Fiorilli et al., (2017), which found no significant difference in COD performance between U-16 and U-18 players. COD is typically influenced by technical factors, such as technique, perception, anticipation, and decision-making during movement execution (Pojskic et al., 2018; Sinkovic et al., 2023). It is possible that the participants, despite their age differences, possessed similar COD skills (Fiorilli et al., 2017; Dugdale et al., 2020). Pojskic et al. (2018) and Dugdale et al. (2020) also indicated that proper movement techniques and technical competency during the COD assessment may influence the results. Sánchez-López et al. (2023) further noted that COD performance is more influenced by isolated technical factors (e.g., lower body braking force, ground contact time, pelvis alignment, and foot placement) rather than by acceleration or linear speed. Therefore, while the tests used to evaluate COD performance are reliable and valid (Rago et al., 2020; Michailidis et al., 2021), further studies are needed to explore agility-related performances and the differences between age groups (Pojskic et al., 2018).

vi. Non-Significant Difference in Explosive Power

Interestingly, no significant differences were found in explosive power between the U-15 and U-18 groups, which contrast with the findings of several previous studies that identified significant differences in lower limb power and when comparing different age groups (Lesinski et al., 2020; Giudicelli et al., 2021; Ke et al., 2021). Several limitations may explain this result, including the relatively small sample size. As Brysbaert (2019) points out, a small sample size can limit the statistical power of the study and lead to questionable conclusions. Andrade (2020) also emphasizes the importance of a larger sample size to produce more reliable and generalizable results. Additionally, the imbalance in sample sizes between the U-15 (n = 8) and U-18 (n = 7) groups could have contributed to errors in interpretation. Despite this, the dataset remains valuable, particularly considering the limited research on young male soccer players (Keiner et al., 2021). Another limitation is the absence of speed-specific training within the CT program. Previous research suggests that the inclusion of speed-specific exercises may enhance the effectiveness of CT in improving speed and power performance (Hammami et al., 2018). Falch et al. (2019) and Carvajal and Salazar (2021) also recommend integrating speed and COD training into CT programs to achieve more significant improvements. Future research could benefit from incorporating speed and COD-specific training alongside CT to determine whether such an intervention leads to more pronounced improvements in athletic performance.

4.7.3 Study Limitations and Future Directions

As stated in the discussion, several limitation of this study must be acknowledged. First, the relatively small sample size (n = 15) may have limited the statistical power of the study. Brysbaert (2019) suggested that larger sample sizes could yield more conclusive results and potentially uncover additional differences in speed, change of direction (COD) and power performance between youth soccer players. Andrade (2020) also emphasized that a larger sample size is needed to produce more reliable and generalized results.

Another limitation that may have affected the post test results is the lack of gold standard measurement to specifically assess the influence of maturity on physical performance. Instead, the study only referred to past research that suggested chronological age could influence maturity, and this was used to analyse the differences in physical testing results. However, it has been established that chronological age is one of the indicators for measuring maturation in young athletes (Lesinski et al., 2020; Giudicelli et al., 2021). França et al. (2021) stated that chronological age is a longitudinal predictor of explosive leg power from childhood to young adulthood and that explosive leg power performance in boys increases linearly from ages 5 to 18. Different chronological age group may influence the physical testing outcomes at the end of the study (Pichardo et al., 2019).

In the future, to obtain more concrete evidence, researchers could use biological age differences instead of chronological age to assess the influence of maturity. This could help identify differences between age groups and yield better results in COD and explosive power performance. Furthermore, based on the findings, it is clear that the duration of the training was not sufficient to observe more significant differences between the two age groups. A longer training period would be needed to detect more pronounced differences. Jovanovic et al. (2011) stated that long-term training adaptations result in higher power-related production. Kyung and Park (2024) indicated that a longer training period is necessary to study the effects of training and analyse the differences between age groups.

Despite these limitations, the results of this study contribute to the ongoing discussion about the role of biological maturation in athletic performance. While chronological age is often used as a primary measure, variations in individual growth rates can influence training responsiveness. Future studies may need to incorporate biological maturity assessments to refine training interventions further. Despite the limitations, the current study provides valuable evidence of differences between two chronological age groups in terms of speed, change of direction, and explosive power. Lastly, this study contributes to the development of scientific knowledge in the area of soccer training, which can help in designing specific training programs to meet the needs of different age groups.

4.8 Conclusion

Soccer is a high-intensity, intermittent contact team sport that demands various physical and physiological capabilities for successful performance. In addition to technical and tactical abilities, players must maintain high levels of aerobic and anaerobic conditioning, speed, change of direction (COD) and power to gain an advantage in the sport. Based on the current findings, complex training (CT) led to moderate to large improvements in linear sprinting, COD performance, and higher CMJ performance among the participants for both groups. These findings indicated that CT training method is an effective strategy for improving sport-specific power performance. Regarding differences between the two groups, future studies could use a larger sample size and a longer training duration, which may yield different outcomes. Additionally, improvements based on the limitations of this study could help achieve more significant results in future research. Despite these limitations, the current findings provide valuable insights for coaches, highlighting the effectiveness of CT in improving sport performance

CHAPTER 5

ENHANCING PERFORMANCE: THE EFFECTS OF COMPLEX TRAINING ON SPEED, CHANGE OF DIRECTION, AND POWER PERFORMANCE IN YOUTH SOCCER PLAYERS

5.1 Abstract

This study aimed to investigate the differences in speed, change of direction (COD), and power performance between the complex training (CT) group and the control group following an eight-week intervention. A total of 29 soccer players (n=29) aged from under 15 (n=14; aged 13–15 years) to under 18 (n=15; aged 16–18 years) were recruited from Sultan Idris Shah II Secondary School, Malaysia. Participants completed three physical tests assessing speed, COD, and power performance as a pre-test. They were then age-matched to either the CT group or the control group. The intervention lasted eight weeks, with the CT group following a complex training program while the control group continued with standard soccer training. The Wilcoxon Signed Rank Test indicated significant improvements across all four assessments: the 20m Sprint Test ($Z=-3.43$, $p=0.01$, median score change from 3.21 to 3.17), the Arrowhead Test (Right) ($Z=-3.41$, $p=0.01$, median score change from 8.25 to 8.11), the Arrowhead Test (Left) ($Z=-3.41$, $p=0.01$, median score change from 8.36 to 8.20), and the Counter-Movement Jump Test ($Z=-3.41$, $p=0.01$, median score change from 37.09 to 41.15). In term of differences, the Mann-Whitney Test revealed only COD, (Right) had significant difference while there were no significant differences were found in speed, COD (Left) and power performance between the two groups. However, these findings contribute to a better understanding of CT's role in athletic development and provide valuable insights for coaches regarding its potential effectiveness in enhancing sports performance.

Keywords: soccer, speed, change of direction, power performance, age and maturity impact, complex training

5.2 Introduction

Over the recent years, modern soccer has drastically changed and undergone a profound transformation which has evolved into a dynamic and high-paced intermittent sport game (Andrašić et al., 2021) which soccer nowadays involved short-duration, high intensity activities, including sprinting, running, jumping, duels, tackling, directional changes, and various instances of walking and standing. A typical soccer match involves athletes executing 150-250 rapid and diverse movements, with activities changing every 3-5 seconds (Brito et al., 2014). This encompasses 30-40 sprints, 30-40 tackling and jumping, as well as moments of deceleration, kicking and dribbling (Brito et al., 2014). By possessing great physiological abilities may benefits in optimizing performance and could enhance tactical implication of the coaches (Zghal et al., 2019; Yu et al., 2021; Keiner et al., 2021). Based on the analysis of the previous studies, speed, change of direction (COD), and explosive power are crucial physical components that significantly enhance soccer player's performance either in technical nor tactical aspects either in adult or youth (Zghal et al., 2019). Speed important when the players try to outpace opponents, make swift transitions, and capitalize on counter-attacks (Zghal et al., 2019; Andrašić et al., 2021). COD allows for effective dribbling, precise defensive positioning, and adaptability in dynamic play situations while explosive power contributes to quick acceleration, impactful shooting, and dominant aerial play (Zghal et al., 2019; Andrašić et al., 2021). Together, these attributes not only improve individual skills but also elevate team dynamics, making them essential for achieving success on the soccer field.

Suitable training programs needed to be applied towards the players especially for the youth athletes so that that they could gain advantages in the sport game (Zghal et al., 2019). There have been many debates about suitable training programs that could be applied to youth athletes because some past researcher stated that they are prone to injuries because of immaturity of the skeletal system (Peitz et al., 2018). Appropriate training method that designed to develop physical qualities and neuromuscular control could offer positive effects to avoid injury while enhancing performance at the same time (Jayanthi et al., 2021). Combining different modes of exercises in single training session to meet physical demands of the athletes have been popular lately (Ali et al., 2019). The training that been proposed called as complex training (CT) which this training combined both resistance training (RT) and plyometric training (PT) in the same training course (Greenwood and Carter, 2014; Ali et al., 2019; Wang et al., 2023).

CT alternates between heavy load RT and followed by biomechanically similar explosive PT exercises (Abdelkader, 2016; Ali et al., 2019; Wang et al., 2023). Previous studies showed that combining RT with PT in the same training course has better outcomes in improving power and its' derivatives factors rather than RT and PT training separately (Zghal et al., 2019) and Ali et al., (2019) stated that CT could induced PT stimulus in enhancing explosive power and its' derivatives factors. This is supported by Kobal et al., (2017) stated that previous studies have revealed combining both RT and PT could induce greater implications and improvements in muscle capabilities when compared to RT and PT alone. Besides that, Ali et al., (2019) also supported these statements by stating that CT was said to be one of the best training method to be used to improve muscular power and its' demands (Ali et al., 2017) but there are still limited studies that have tried to promote the importance and effectiveness of complex training (CT) towards athlete performance (Talpey et al., 2016). This is because, some of past studies had found that not all physical fitness that been tested have significantly improve after given CT training program. This is supported by Chen et al., (2017) as stated in Jusoh et al.,(2019) which in the study, the researcher not recommended complex training in a team training regime because some athletes may negatively impact their performance, while others showed improvement. However, this statement is due to further confirmation because of different protocols used (Jusoh et al., 2019).

Additionally, previous study observes that there was a small positive effect towards jumping performance within 2 times per week frequency of training for a whole 6 weeks (Freitas et al., 2017) however, in another study by Freitas et al. (2017) to improve jumping performance by using CT protocols, the training duration must be more than 6 weeks. To create more concrete evidence to the effectiveness of CT and to fill the gap that being left, this current study followed Abdelkader (2016) CT protocols and tried to utilize 3 times per week of training and been done for 8 weeks. Besides that, the current study also aimed to investigate the differences between the between the complex training (CT) group and control group in speed, change of direction (COD) and power performance after underwent 8 weeks of CT.

5.3 Method

5.3.1 Research Design

The experimental design for this study was a pre-test post-test design. The participants were divided into two groups: the complex training (CT) group (n=15) and control group (n=14). The CT group underwent an eight-week CT programs, while the control group followed standard technical and tactical soccer training. The pre-test data collection procedures were identical to those described in Chapter 3, and the data from Chapter 3 were used as the pre-test data for this study.

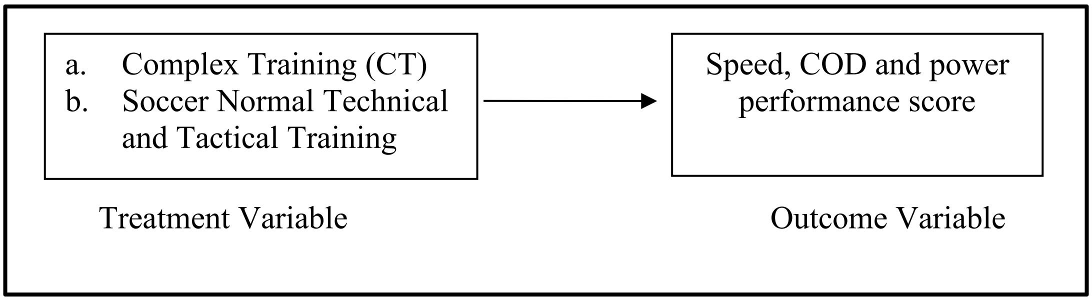

Figure 5.1 Conceptual Framework

5.3.2 Population/ Sample/Participants/Sampling Technique

Twenty nine players (n=29) aged under 15 (13-15 years) and under 18 (16-18 years) were enrolled in this study. They were then age-match assigned into two groups the CT group (U-15=8, U18=7) (n=15, mean ± SD; aged = 15.33 ± 1.07 years; height = 1.65 ± 4.65m; body mass = 53.45 ± 6.38kg) and control group (U-15=6, U18=8) (n=14, mean SD; aged = 15.43 ± 1.18 years; height = 166.29 ± 6.8cm; body mass = 55.71 ± 8.8kg). We excluded the goalkeeper to avoid tampering the final result.

5.3.3 Instrumentation and Instrument

4.3.3.1 Instrument

a) Gym Equipment

The gym equipment was used for resistance training (RT). All equipment was sourced from Sekolah Menengah Sultan Idris Shah II's gymnasium. The equipment included an Olympic bar, dumbbells, weight plates and assisted machines such as the leg extension machine and leg press machine.

b) Plyometric Equipment

The plyometric equipment was used for plyometric training. All equipment was obtained from Sekolah Menengah Sultan Idris Shah II's gymnasium. The equipment included boxes and hurdles, with heights ranging from 20cm to 60cm.

4.3.3.2 Instrumentation

a) Pre-Test

The pre-test protocols used were the same as those in Chapter 3, including the data for anthropometric measurements and assessments that had been used, namely the 20m sprint test, Arrowhead Test and Counter-Movement Jump test (CMJ).

b) Intervention

The complex training (CT) group participated in CT sessions three times per week, conducted by the researcher. After completing the CT sessions, they engaged in normal technical and tactical soccer training, while the control group only participated in normal technical and tactical soccer training. The final results determined the effectiveness of CT and the differences between the two groups. The CT training program that was used is outlined below:

i. Complex Training

The training was adapted and adopted from Abdelkader (2016). The resistance training (RT) involved the use of dumbbells, barbells and Olympic bar, focusing on the lower extremities (2 sets of 3-8 repetitions, with a range of 70-95% of 1RM). The plyometric training involved the use of boxes and hurdles, with the height ranging from 20-60cm. The plyometric training was done after the RT and included 2 sets of 6-10 repetitions of plyometric jumps in the same session. The rest interval ranged from 2-3 minutes. The training was done before soccer team training and after they were done with the training, they will join the team training. The CT alternated with the rest day (No CT done in that day). The training day mostly done on Monday, Wednesday and Friday but sometimes changed to Tuesday, Thursday and Saturday if the team has one day off during that week. The training program is outlined in Table 4.1.

ii. Normal Soccer Technical and Tactical Training

Normal soccer training was conducted after completing CT in each session. This training involved both technical and tactical aspect of soccer. Additionally, physical training, such as sprinting, changing direction and power training was incorporated, using only used body weight.

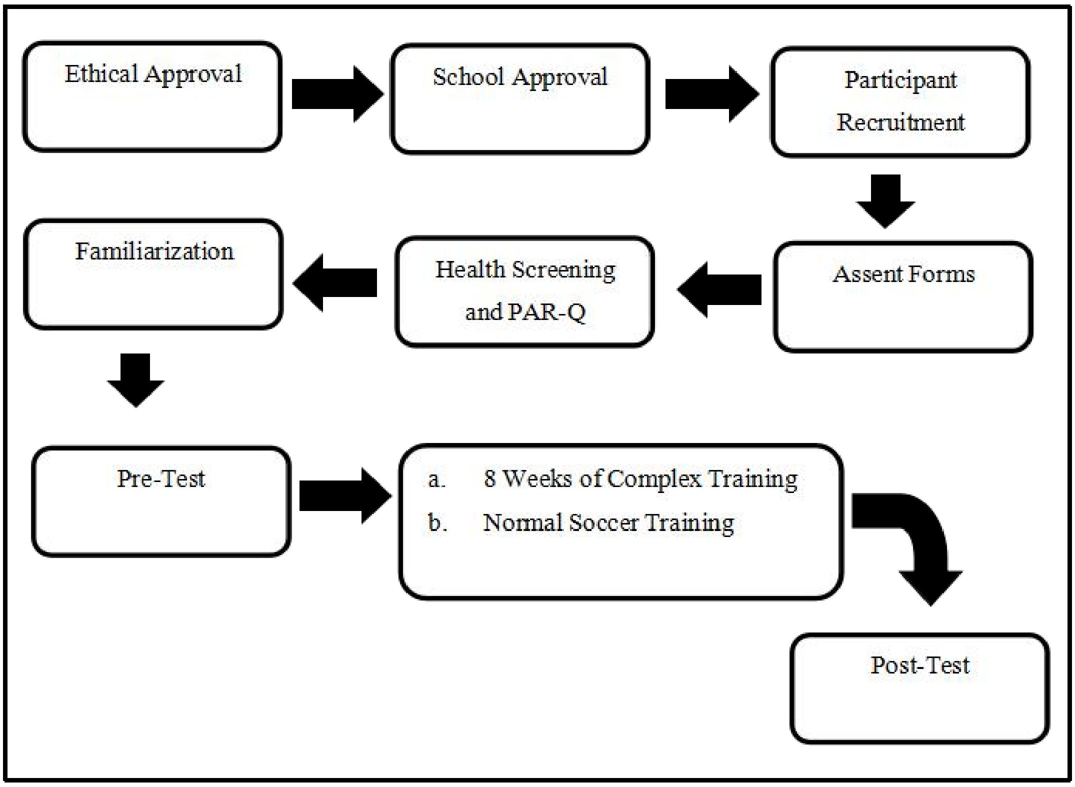

Figure 5.2 Research Flow Chart

5.4 Data Collection Procedures

The current study used the same procedures from Chapter 3 for health screening and assent forms, which were signed by the participants' parents or guardians. The study also followed the same assessment protocols as in Chapter 3, with all data collected in Chapter 3 serving as pre-test data for the current study. As stated, the study began a week after the study in Chapter 3 was completed (as shown in Figure 5.3).

5.4.1 Group Allocation Procedure

The participants were divided into two groups: the complex training (CT) group (n = 15) and the control group (n = 14). Group allocation was conducted using age-matched procedures, whereby athletes from the U-15 and U-18 categories were proportionally distributed between the CT and control groups to ensure comparable age representation. This approach was implemented to control for chronological age differences and to ensure that performance outcomes reflected the effects of the training intervention rather than age-related variation. The CT group participated in complex training sessions three times per week in addition to their regular soccer training for eight weeks, following the same training protocol described in Study 2. The control group continued with their normal soccer training without additional intervention. Post-testing was conducted in the eighth week, and the collected data were subsequently analysed.

5.4.2 Post-Testing Control Procedures

Post-testing was conducted 48–72 hours after the final training session to minimise the potential influence of residual fatigue. Participants were instructed to avoid additional strenuous physical activity during this recovery period. The post-test assessments were performed under conditions consistent with the pre-test, including standardized warm-up procedures, similar time of day, and identical testing protocols. These procedures were implemented to ensure that performance outcomes reflected training adaptations rather than acute fatigue effects.

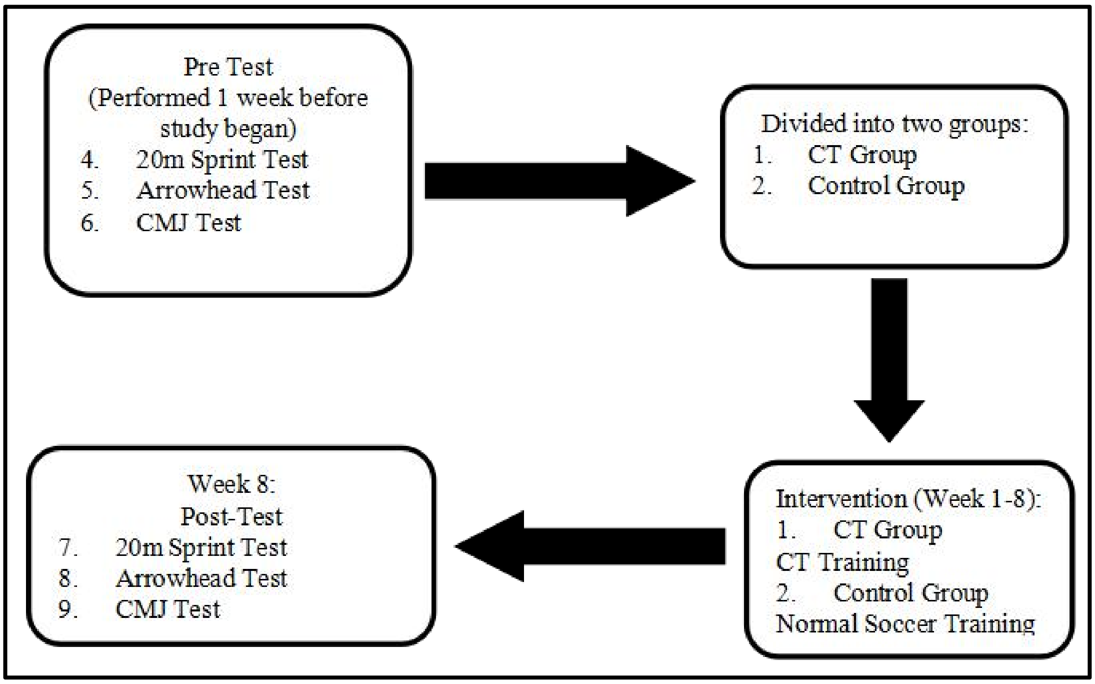

Figure 5.3 Data Collection Procedures

5.5 Data Analysis

To interpret the data for this study, Statistical Package for Social Science (IBM SPSS Version 25) was used. The data obtain from both pre-test and post-test data of

20 m sprint test, arrowhead test and counter-movement jump (CMJ) test were presented in descriptive analysis as mean and standard deviation (SD) to analyse the effects of CT before and after underwent 8 weeks of CT. Besides that, Wilcoxon Signed Rank Test was used to investigate the effects of 8 weeks of complex training in speed, change of direction (COD) and power performance in the CT and control group. To compare the differences between the two groups, researcher used Mann-Whitney Test.

5.6 Result

5.6.1 Descriptive Analysis

Table 5.1
Demographic Analysis of the CT Group and Control Group

Variables	CT Group (n=15) Mean ± SD	Control Group (n=14) Mean ± SD
Age (years)	15.33 ± 1.07	15.43 ± 1.18
Weight (kg)	53.45 ± 6.38	55.71 ± 8.80
Height (cm)	165.3 ± 4.65	166.29 ± 6.8

Table 5.1 above presents the demographic characteristics of the CT and control groups, including age, weight and height. The data are expressed as mean ± standard deviation (SD).

Table 5.2
Descriptive Analysis of Pre- and Post-Test Results for the CT and Control Groups

Variables	CT Group (n=15)		Control Group (n=14)	
	Pre-Test Mean ± SD	Post-Test Mean ± SD	Pre-Test Mean ± SD	Post-Test Mean ± SD
20m Sprint Test (s)	3.20 ± 0.10	3.15 ± 0.10	3.17 ± 0.07	3.16 ± 0.07
Arrowhead Test (Right) (s)	8.31 ± 0.25	8.14 ± 0.17	8.37± 0.27	8.31 ± 0.23
Arrowhead Test (Left) (s)	8.37 ± 0.25	8.25 ± 0.22	8.46 ± 0.27	8.40 ± 0.24
CMJ Test (cm)	37.68 ± 5.70	42.45 ± 4.97	39.77 ± 3.99	40.96 ± 4.40

Table 5.2 presents the pre-test and post-test performance metrics for the CT and control groups across four variables: the 20 m sprint test, arrowhead test (right and left), and counter-movement jump (CMJ) test. The results are expressed as mean ± standard deviation (SD).

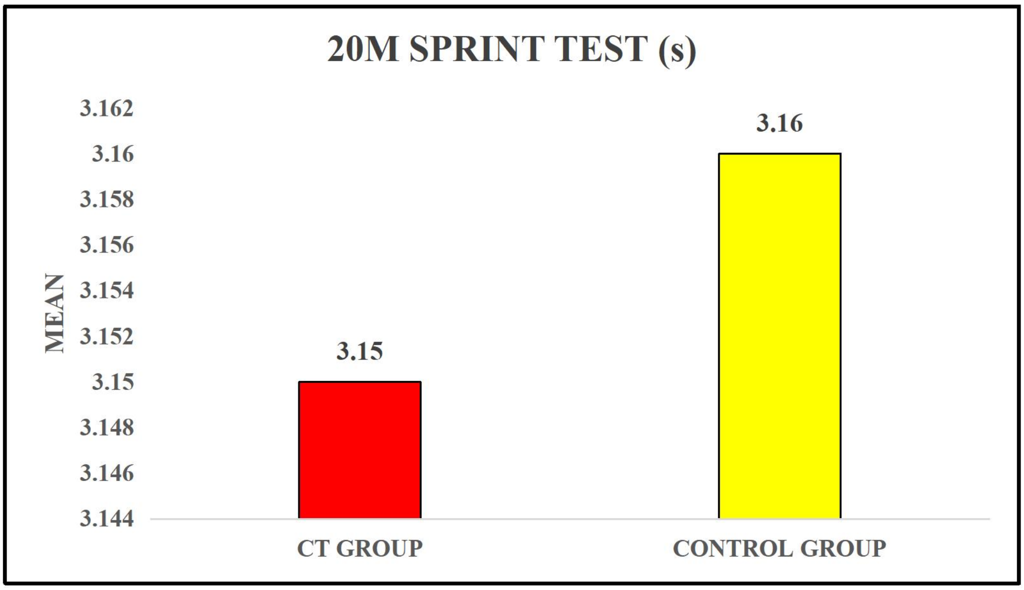

Figure 5.4 Performance Differences between CT and Control Group in 20m Sprint Test

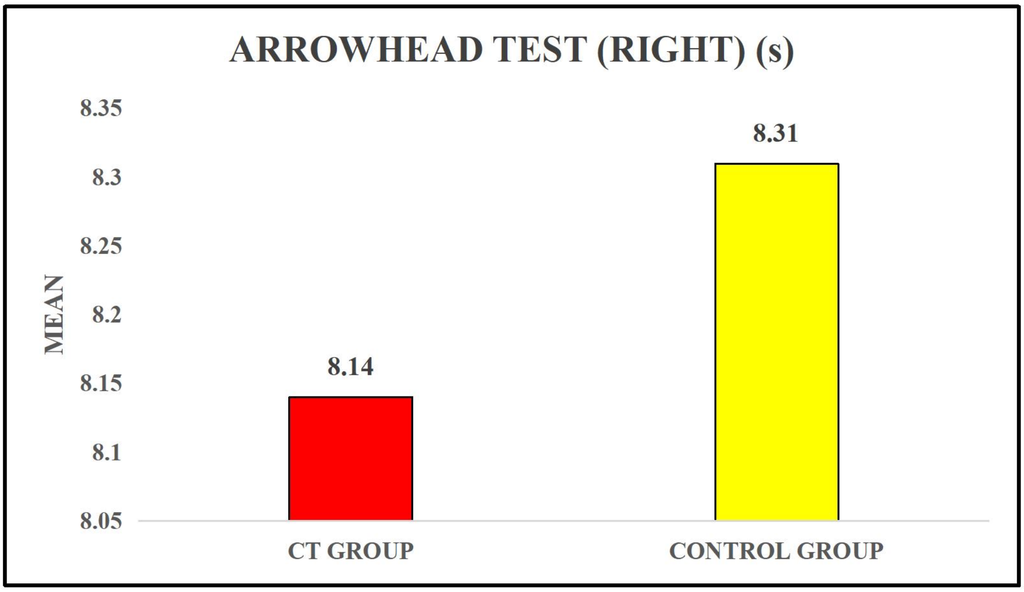

Figure 5.5 Performance Differences between CT and Control Group in Arrowhead Test (Right)

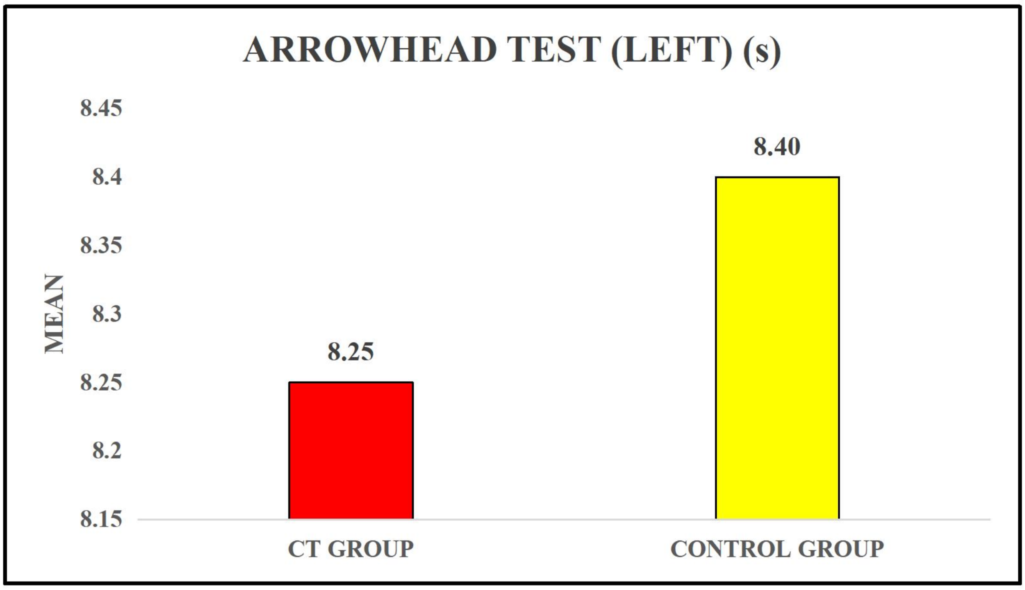

Figure 5.6 Performance Differences between CT and Control Group in Arrowhead Test (Left)

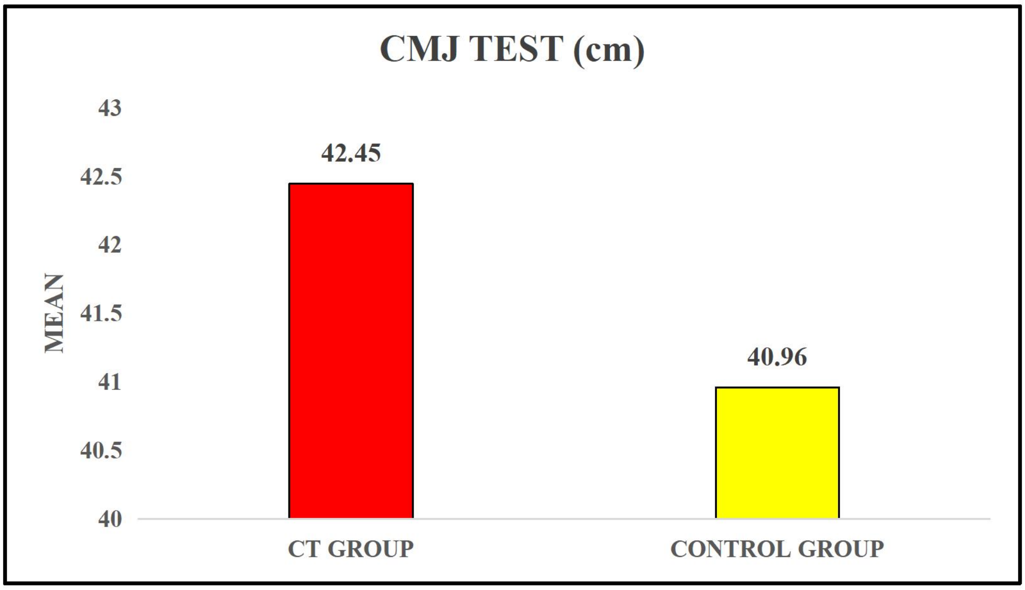

Figure 5.7 Performance Differences between CT and Control Group in CMJ Test

Figure 5.4 to 5.7 illustrates the post-test mean performance values for the CT and control groups across four assessments: the 20m sprint test, Arrowhead Test (right and left), and the Countermovement Jump (CMJ) test. The bar chart visually compares the effects of CT training with the control group, highlighting improvements in speed, change of direction, and explosive power.

5.6.2 Inferential Analysis

Based on Table 5.3, the Wilcoxon Signed Rank Test showed a statistically significant improvement in performance following 8 weeks of CT intervention (3 sessions per week). The 20m sprint test showed a significant reduction in sprint time ($Z = -3.43$, $p = 0.01$), with the median improving from 3.21 to 3.17 seconds. Similarly, the Arrowhead Test (Right) demonstrated significant improvement ($Z = -3.41$, $p = 0.01$), with the median decreasing from 8.25 to 8.11 seconds, while the Arrowhead Test (Left) also showed a significant reduction ($Z = -3.41$, $p = 0.01$) from 8.36 to 8.20 seconds. Additionally, the Countermovement Jump (CMJ) test exhibited a significant increase in jump height ($Z = -3.41$, $p = 0.01$), with the median rising from 37.09 cm to 41.15 cm. These findings indicate that speed, agility, and power were all significantly enhanced by the 8-week CT training program.

Table 5.3
Effects of CT on Speed, Change of Direction and Power Performance.

	Pre-Test		Post-Test		Wilcoxon Signed Rank Test Probability	
	Mean ± SD	Median	Mean ± SD	Median	Z	p-value
20m Sprint Test (s)	3.2 ± 0.11	3.21	3.15 ± 0.10	3.17	-3.43	0.01*
Arrowhead Test (Right) (s)	8.31 ± 0.26	8.25	8.14 ± 0.17	8.11	-3.41	0.01*
Arrowhead Test (Left) (s)	8.37 ± 0.26	8.36	8.25 ± 0.22	8.20	-3.41	0.01*
CMJ Test (cm)	37.68 ± 5.90	37.09	42.45 ± 5.15	41.15	-3.41	0.01*

*Indicate significant difference , p≤0.05

Table 5.4
Differences in Performance between CT and Control Group after 8 weeks.

	CT Group (n=15)	Control Group (n=14)	Mann-Whitney U Test			
	Mean Rank	Mean Rank	U	Z	P-value	Effect Size (r)
20m Sprint Test (s)	14.90	15.11	103.50	-0.07	0.95	-0.01
Arrowhead Test (Right) (s)	12.03	18.18	60.50	-1.94	0.05*	-0.36
Arrowhead Test (Left) (s)	12.63	17.54	69.50	-1.55	0.12	-0.29
CMJ Test (cm)	16.10	13.82	88.50	-0.72	0.47	-0.13

*Indicate significant difference, $p \leq 0.05$

The Mann-Whitney U test revealed no significant differences between the complex training (CT) group (n=15) and control group (n=14) in speed (20m Sprint: U=103.50, Z=-0.07, p=0.95; mean ranks CT=14.90 vs. Control=15.11), power (CMJ Test: U=88.50, Z=-0.72, p=0.47; mean ranks CT=16.10 vs. Control=13.82), or left-side agility (Arrowhead Test Left: U=69.50, Z=-1.55, p=0.12; mean ranks CT=12.63 vs. Control=17.54) after 8 weeks. However, a borderline significant improvement was observed in the CT group for right-side agility (Arrowhead Test Right: U=60.50, Z=-1.94, p=0.05; mean ranks CT=12.03 vs. Control=18.18), suggesting potential benefits for unilateral change-of-direction performance. However, this result should be interpreted cautiously due to its marginal significance. All other outcomes, including sprint speed and vertical jump power, showed no statistically significant group differences (p>0.05), leading to acceptance of the null hypothesis for most measures. The findings indicate limited overall efficacy of the CT intervention on the tested performance metrics.

5.7 Discussion

5.7.1 Effects of Complex Training (CT) on Speed, Change of Direction (COD) and Power Performance in CT Group

The findings of this study revealed CT group have shown significant improvements after undergoing an 8-week complex training (CT) intervention in all component measured. CT has been widely recognised in the literature for enhancing lower body power (Lim & Barley, 2016), an is especially relevant for soccer, where high-intensity, explosive movements such as sprinting, change of direction (COD), and jumping are crucial for performance (Freitas et al., 2017). Our study's findings were align with past study as in Thapa et al., (2020) which in the past study found that CT intervention has induced moderate to large improvement in linear sprinting, COD performance and higher in CMJ performance. The improvements observed in the current study could be explained by three primary physiological mechanisms: Post-Activation Potentiation (PAP), physiological changes, and hormonal and cellular adaptations.

i. Post-Activation Potentiation (PAP)

CT induced PAP response of the muscle Thapa et al., 2020). PAP is where neuro-muscular condition observed in the skeletal muscle after an initial bout of heavy resistance exercise (Lim and Barley, 2016). PAP has been demonstrated to enhance the rate of force development in the targeted muscle groups, resulting in an increasing of acceleration and velocity in the working muscles during movements executions which in turn, can lead to acute and long-term improvements in muscular strength and power (Lim and Barley, 2016). This is due to greater percentage of type II muscle fibers caused larger generation of maximal muscle contractions due to a higher initial anaerobic force rate and produce greater metabolites associated with fatigue and improve PAP response in align with the CT intervention (Golaz et al., 2016; Wang et al., 2023).

Extremely heavy loads used in the training caused higher recruitment of type IIx muscle fibers which provided significant effect on PAP during the maximal intensity and short duration movements (Golaz et al., 2016; Wang et al., 2023). Thapa et al., (2020) proposed that power production improved due to increasing of type IIx muscle fibers that cause greater contraction velocity, explosive power production and rate of force development compared to type IIA and type I muscle fibers. Because of this, the athletes underwent physiological adaptation that regulates the myosin light chain phosphorylation which increase the regulation of actin-myosin for calcium ions (Ca2+), alter the myosin head structure and produce higher cross-bridge force output and muscle pre-contraction which increase greater potential across the spinal cord resulting in higher motor unit recruitment (Chen et al., 2017). Jusoh et al., (2019) also stated that CT enhance the coordination of motor unit activation and recruitment that cause increased of peak height and reduce contact duration during the stretch-shortening cycle (SSC) that cause higher jumping performance. The combined RT and PT intervention helped in improving the storage of the elastic energy during the deceleration phase and produce greater the shortening positive phase enhancing muscle force and power production which later may induced the maximal strength enhancement which then contribute to higher force production during the movement execution (Abdelkader, 2016; Zghal et al., 2019).

ii. Physiological Changes

Grgic et al., (2021) indicated that CT provide positive effects in increasing the muscle size. Combination of resistance training (RT) and plyometric training (PT) in the same training course give addictive effects in increasing muscle thickness and induced significant changes in muscle cross-sectional areas and positive changes in muscle size. This is supported by Schneiker et al., (2023) strength-power training regime caused the improvement of muscle cross-sectional area, muscle architectural changes, muscle hypertrophy and muscle tendinous which these neuromuscular and morphological adaptation influenced the explosive movement execution performance. This is due to higher recruitment of type IIx muscle fibers which associates with the response towards to CT intervention movements execution and PAP response cause greater potential of hypertrophy effects. Even though there were quite arguments that correlates muscle hypertrophy to maximal strength production because some past studies indicates that changes in strength may occur without change in muscle size, but we must not exclude muscle size improvement may contribute to maximal strength production (Vigotsky et al., 2018). This is supported by Reggiani and Schiaffino (2020) stated that changes in the athletes' muscle architectural and size caused contractile performance and higher force generation of the muscle during movements execution This is also supported by Thapa et al., (2020) which in the study stated that power production may increase due to increasing of type IIx muscle fibers that cause higher contraction velocity, explosive power production and rate of force development compared to type IIA and type I muscle fibers.

iii. Hormonal and cellular adaptations

After been exposed to 8 weeks of CT intervention caused higher production of testosterone hormone which may result in better outcomes in power production in the youth athletes (Greenwood and Carter, 2014). This is because testosterone hormone that produced due to 8 weeks intervention may affect towards the changes that happened in the physical development of the athletes like muscle mass and strength (Vanny and Moon, 2015) which this type of hormone production may result in higher strength-power production when executing the movement (Ali et al., 2019; Thapa et al., 2020). These hormone regulation helps the athletes' physiological response in multitude of ergogenic, anabolic, and anti-catabolic functions in the skeletal muscle which help in possessing greater muscle strength, power, endurance (Gharahdaghi et al., 2020). This is supported by Zouhal et al., (2022) which in the study stated that exposing the athletes to high intensity exercises may lead in greater production of testosterone hormone and may affect the muscle mass and strength production.

5.7.2 The Differences between the Complex Training (CT) Group and Control Group in Speed, Change of Direction (COD) and Power Performance after 8 Weeks of Intervention

Current findings indicated that there were significance difference in change of direction (COD) (Right) between the two groups while there were no significance differences in speed, change of direction (COD) and power performance although when trying to prove the effectiveness of complex training (CT) showed that there were significant effects after the 8 weeks of intervention in these physical components. These happened due to few factors which as below:

i. Importance of Speed, COD and Power in Soccer

Modern soccer is characterized by short-duration, high intensity activities which speed, change of direction (COD) and power capabilities played critical roles in success in this type of invasive sport (Pavillon et al., 2021; Gualtieri et al., 2023). Players who possessed good speed,quick COD and lower limb explosive power abilities may affect the team's performance not only in adult but also in youth soccer game (Zghal et al., 2019; Andrašić et al., 2021) which attackers rely on these abilities to apply pressure and execute tackles to gain goal scoring opportunities, while defenders use them to close down opponents' space and limit attacking opportunities, thus minimizing threats to the team which may lead to concede goals (Andrašić et al., 2021). Besides that, by having great physical abilities will automatically optimizing performance and could enhance tactical implication of the coaches (Zghal et al., 2019; Yu et al., 2021; Keiner et al., 2021). Previous studies suggest that mature players tend to exhibit better sport-related performance (Radnor et al., 2017; Radnor et al., 2021). Due to scarcity of research on how complex training could enhance physical abilities in youth players (Talpey et al., 2016, Peitz et al., 2018), this study tried to analyze the effects of CT after 8 weeks intervention. Based on the result, only COD (Right) shown difference between the two groups while speed, COD (Left) and power performance did not show any differences after the 8 weeks intervention ended. Few factors throughout the study process influenced the final results which are leg dominance and preferance, no specific speed-agility related drills, technical factor and athletes' training status and short duration of training.

ii. Leg Dominance and Preferance

After been exposed to 8 weeks of complex training (CT), the dominant leg may exhibited higher improvements in change of direction (COD) performance compared to the non-dominant leg which caused may influence the end results of the arrowhead test which shown only the right side had significance result while the left did not. Most of the participants from CT group are right-footed which 8 weeks of CT intervention combined with soccer specific technical and tactical training may enhance the functionability of the right leg. CT which combined high-load resistance training (RT) followed by plyometric training (PT) has been demonstrated to give addictive effects in improving in physiological changes of the muscles and could improved overall COD ability in young athletes who have a higher capacity for neuromuscular adaptation (Grgic et al., 2021; Thapa et al., 2021). Schneiker et al., (2023) indicated that strength-power training regime caused the improvement of muscle cross-sectional area, muscle architectural changes, muscle hypertrophy and muscle tendinous which these neuromuscular and morphological adaptation influenced the explosive movement execution performance. This is due to higher recruitment of type IIx muscle fibers which associates with the response towards to CT intervention movements execution and PAP response cause greater potential of hypertrophy effects which eventually affect the COD performance. (Golaz et al., 2016; Thapa et al., 2021; Wang et al., 2023).

Furthermore, CT could enhance the muscles' stretch shortening cycles (SSC) especially in the dominant leg which allowed the players to perform specific tasks as COD itself effectively with higher levels of eccentric strain on their muscles (Sarkar and Bhattacharya, 2024). Thus, this caused the players tend to have greater right leg capabilities than their left leg which they tend to have better coordination in the muscles and nerves when performing the COD (Right) movements which then influence the technique, perception, anticipation, and decision-making during movement execution (Pojskic et al., 2018; Clemente et al., 2022; Sinkovic et al., 2023). Besides that, their muscles may tend to experienced changes in term of lower limb knee extensor and flexors ability, lower body braking force, ground contact time, pelvis alignment, and foot placement (Clemente et al., 2022; Sánchez- López et al., 2023). This is supported by previous studies indicating that players performed better in COD specific task with their dominant leg rather than their non-dominant leg because the dominant leg is often often has greater strength, functional capacity and used more frequently during sport-specific actions such as cutting, sidestepping, and rapid changes of direction (Rouissi et al., 2016; Clemente et al., 2022). However, study by Železnik et al., (2025) stated that this statement still remained unclear as the finding in the study shown that the usage of dominant and non-dominant leg when the players are still in youth category were quite similar and not consistent when performing specific task such as COD. Thus, in the context of youth soccer, further investigations are required to explore agility-related performances and the differences on dominant and non-dominant leg effects when performing COD specific tasks after underwent specific training (Pojskic et al., 2018; Clemente et al., 2022; Železnik et al., 2025). The current findings may provide some insights on the influence of leg dominance on COD performance and encourage future research to examine limb-specific adaptations in young athletes especially in context of youth soccer players

iii. No Specific Speed and Agility-Related Drills

Current study did not involved any specific speed and agility-related drills in the CT program (Hammami et al., 2018). Previous study by Poulos et al., (2010) have used this type of training which added in the CT program found that to be effective in increasing maximal sprint of the athletes which in this case, may affect the differences between the two groups. This statement was supported by Falch et al., (2019) which pointed that combination of specific speed and COD training movement in training program may lead to more beneficial results in term of linear speed and COD movements of athletes' development. This is align to what stated in Carvajal and Salazar (2021) as in the study stated that several authors have agreed that added speed-specific training program in training regime may enhance the performance. If speed and COD programs was added in the CT program may lead to better results to show the differences between the two groups (Kuitenan et al., 2010; Hammami et al., 2018; Falch et al., 2019; Carvajal and Salazar, 2021). This also helped in avoiding variation of results in COD performances..

iv. Technical Factor and Athlete's Training Status

Another justification of the non-significant results may due to technical factors and athletes' training status during the whole training intervention period and also during the testing (Hammami et al., 2018; Silva et al., 2022). Linear and changing direction technique quality may influence the result of speed and variation of the COD results in this current study (Pojskic et al., 2018; Silva et al., 2022). It is possible that individuals may have adopted a more effective technique, resulting in a decrease in their body mass and may experience favorable psychological or hormonal influences that can impact their performance during testing (Cavaco et al., 2014; Pojskic et al., 2018; Silva et al., 2022). Even though the different of training applied on both groups in the current study, but, both group underwent soccer specific training which in the training also involved speed and COD training as both elements were crucial in sport like soccer (Silva et al., 2022). This may affect the post-results. This may also result in no significant differences between the two groups. This statement was supported by Kirby et al., (2010) that stated that sprint training outside of weight training room may also result in improving muscle function and helps in improving pre-activation muscles in the eccentric phase of the SSC activities. To improve the findings to show the differences between the experimental and control groups, future study could add some sprint and COD specific skills in the CT programs which later result in better result to study the difference between the two groups and better technique performed among the studies' participants (Pojskic et al., 2018; Hammami et al., 2018; Falch et al., 2019; Silva et al., 2022).

v. Non-significant Differences in Power Performance

Contrary with the findings of the previous studies in Table 2.1, the current study did not find any significance differences in term of power performance. This is because, relatively small sample size used in the study may tampered the end result. Bigger sample size may lead better result to justify the differences between the two groups. This is supported by Brysbaert (2019) pointed that bigger sample size could influence the end results and might have different outcomess. Furthermore, insufficient training duration also one of factor that cause the non-significant result. Based on the findings, to justify any differences between two age groups in youth category, our training duration did not enough. More longer training needed for the study groups to adapt with the training so that more bigger differences could be observed between the two studied groups. This is supported by Jovanovic et al., (2011) which stated that long-term adaptations of training will result in higher power-related production. Kyung and Park (2024) indicated that longer period of training required to study the effects of training which in this case to analyse the differences between the two groups. In future study, it is recommended to increase the sample size and increase duration of intervention to gain more substantial end results.

5.7.3 Study Limitations and Future Directions

As discussed, several limitations for this study must be acknowledged. First, the study did not incorporate a speed-specific training program into the complex training (CT) intervention (Hammami et al., 2018). Combining speed-specific and change of direction (COD) training within a training program may yield greater benefits in term of linear speed and COD development in athletes (Falch et al., 2019). Carvajal and Salazar (2021) support this, stating that implementing a speed-specific training program within a training regime can enhance performance. Future studies should incorporate specific speed and COD movements to obtain more concrete results on long-term adaptations and to analyze differences between groups. Including speed and COD programs in CT interventions may lead to clearer distinctions between groups and improved performance outcomes (Kuitenan et al., 2010; Hammami et al., 2018; Falch et al., 2019; Carvajal and Salazar, 2021).

Another limitation of this study was the insufficient training duration, which may have affected post-test results. Longer training periods are necessary to observe long-term adaptations and analyse differences between groups at the conclusion of a study (Jovanovic et al., 2011; Kyung and Park (2024).

Additionally, the relatively small sample size (n = 29) may have limited the statistical power of the study. Brysbaert (2019) suggests that larger sample sizes can yield more conclusive results and potentially reveal additional differences in speed, COD, and power performance among youth soccer players. Andrade (2020) also emphasizes the need for larger sample sizes to produce more reliable and generalize results.

Despite the limitations, the study provides valuable evidence supporting the effectiveness of CT in improving soccer-specific demands such as speed, COD and power performance. Furthermore, it contributes to the scientific knowledge in soccer training and may assist in developing more specialized training programs tailored to the specific requirements of different age groups.

5.8 Conclusion

In conclusion, complex training (CT) programs have demonstrated significant effectiveness in enhancing performance among youth athletes. By integrating strength and power training, these programs improve athletic performance by increasing neuro-muscular efficiency and enhancing motor skills. Research indicates that CT could lead to greater improvements in speed, COD, power performance and overall athleticism compared to traditional training methods. Given that modern soccer is a high-intensity, fast-paced sport requiring physical and physiological capabilities, CT has proven to be an effective method for strength and conditioning coaches aiming to improve players' physical performance.

Additionally, CT promotes better adaptation to physical demands, which is crucial during developmental stages. However, it is essential to implement these programs with proper oversight and tailored approaches to individual needs, ensuring safety and promoting long-term athletic development. When executed correctly, CT stands out as one of the most effective training methods for enhancing the growth and performance of the youth athletes. Consistent with the current findings, CT has demonstrated moderate to high effectiveness and serves as a valuable strategy for improving sport-specific power performance. Moreover, these findings provide valuable insights for coaches, reinforcing the role of CT in enhancing athletic performance

CHAPTER 6
GENERAL DISCUSSION

6.1 General Discussion

Chapter 3 (Study 1) and Chapter 4 (Study 2) explored the influence of chronological age on athletic performance and the effects of complex training (CT) across two different age groups. Specifically, Study 1 examined the impact of chronological age group on speed, change of direction (COD), and explosive power in U-15 and U-18 soccer players. Study 2 investigated differences between these age groups in speed, COD, and power performance following an 8-week CT program. Study 3 (Chapter 5) further examined differences between a CT group and a control group in speed, COD, and power performance after an 8-week intervention.

i. Findings from Study 1

Study 1 identified a significant difference in explosive power ($p = 0.04$) and a trend toward significance in speed ($p = 0.05$) between the U-15 and U-18 players. However, no significant differences were found in COD performance (Arrowhead Test Right: $p = 0.14$, Arrowhead Test Left: $p = 0.35$). Despite the lack of statistical significance, descriptive analysis showed that U-18 players consistently outperformed U-15 players across all measured components: [Speed (20m Sprint Test): U-18: 3.16 ± 0.10 vs. U-15: 3.23 ± 0.09; COD (Arrowhead Test Right): U-18: 8.28 ± 0.28 vs. U-15: 8.45 ± 0.29; COD (Arrowhead Test Left): U-18: 8.39 ± 0.29 vs. U-15: 8.49 ± 0.29; Explosive Power (CMJ): U-18: 40.37 ± 4.92 vs. U-15: 36.66 ± 4.33].

ii. The Role of Chronological Age in Athletic Performance

These results suggest that chronological age contributes to differences in physical performance, as older players tend to develop superior muscle power and speed. This aligns with previous research showing that maturation leads to greater force production, improved muscle stretch-shortening cycle (SSC) function, and enhanced lower limb strength, all of which are crucial for jumping and sprinting (Kurihara et al., 2021).

Additionally, neuro-muscular development, increased androgen circulation, and improved motor unit recruitment give older players an advantage in physical performance (Peitz et al., 2018; Pichardo et al., 2019; Kumar et al., 2021). However, the lack of significant differences in COD performance suggests that factors beyond physical maturation, such as technical skills, perception, anticipation, and decision-making, play a crucial role in COD ability (Sariati et al., 2020; Sinkovic et al., 2023). Previous studies indicate that COD skills may develop independently of age, emphasizing the importance of technique over physical strength (Fiorili et al., 2017; Dugdale et al., 2020).

iii. Findings from Study 2

Since Study 1 did not include a structured training intervention, Study 2 examined how an 8-week CT program influenced speed, COD, and power performance in both age groups. After completing the training, both U-15 and U-18 players showed significant improvements across all performance measures. However, no significant differences were found between the two groups after training ($p > 0.05$). This suggests that CT effectively enhances performance regardless of age, potentially due to: i) Biomechanical adaptations that refine running mechanics and enhance motor control (Pavillon et al., 2020), ii) Improved neuromuscular efficiency, allowing better use of the SSC mechanism for greater force production during sprinting (Radnor et al., 2017; Marzouki et al., 2022) and iii) Enhanced elastic energy utilization and coordination, leading to more efficient sprint and COD execution (Radnor et al., 2021).

iv. The Impact of Technical Factors

Technical aspects, such as sprinting mechanics, body posture, and motor coordination, likely contributed to the findings (Pojskic et al., 2018; Silva et al., 2022). Since both groups participated in regular soccer training, improvements in sprint execution and COD technique may have minimized differences between them. In terms of COD, individual proficiency in braking force, ground contact time, pelvis alignment, and foot placement can significantly impact performance (Sánchez-López et al., 2023). This may explain why no major differences were found between U-15 and U-18 players in COD performance, as cognitive and perceptual skills play a crucial role in executing directional changes effectively (Pojskic et al., 2018; Sariati et al., 2020; Sinkovic et al., 2023).

v. Findings from Study 3

Study 3 investigated the effects of CT compared to a control group in speed, COD, and power performance after an 8-week intervention. Since previous research has shown mixed results regarding CT's effectiveness (Talpey et al., 2016), this study followed Abdelkader's (2016) CT protocol to ensure a structured approach. After 8 weeks, the CT group demonstrated significant improvements across all measures ($p \leq 0.05$): 20m Sprint Test: $p = 0.01$; Arrowhead Test Right: $p = 0.01$; Arrowhead Test Left: $p = 0.01$; CMJ Test: $p = 0.01$.

However, when comparing the CT group to the control group, no significant differences were found ($p > 0.05$) in measured components except in COD (Right). This could be due to several factors: i) Training Duration – A longer intervention may be needed to see more distinct group differences (Kyung & Park, 2024), ii) Lack of Sprint-Specific Drills – CT alone may not fully optimize speed and COD improvements. Research suggests that including sprint-specific training could enhance these adaptations (Hammami et al., 2018; Falch et al., 2019; Carvajal & Salazar, 2021) and iii) Movement Mechanics – Sprinting and COD rely on proper technique, reaction time, and neuromuscular coordination. Since both groups participated in regular soccer training, natural improvements in technique may have minimized performance differences (Cavaco et al., 2014; Pojskic et al., 2018).

The findings from Studies 1, 2, and 3 contribute to the ongoing discussion on age-related athletic development and the effectiveness of CT in youth soccer players. While chronological age appears to influence physical performance, CT proves to be an effective training method regardless of age, highlighting the importance of age-appropriate training strategies that cater to the developmental needs of young athletes.

vi. Future Research Considerations

To strengthen future research, larger sample sizes and longer training durations should be used. A higher frequency of CT sessions and the integration of sprint and agility-specific drills could yield clearer distinctions between training adaptations

(Jovanovic et al., 2011; Kyung & Park, 2024). Additionally, incorporating biological maturation assessments alongside chronological age could provide a more comprehensive understanding of developmental differences. Given the observed improvements in speed, COD, and power, CT remains a valuable training strategy for enhancing youth soccer performance. However, longer intervention periods and refined methodologies are needed to fully differentiate training effects between groups.

6.2 Conclusion

This study had three main objectives. Chapter 3 (Study 1) examines the effects of chronological age group on speed, change of direction (COD) and explosive power in U-15 and U-18 soccer players. Chapter 4 (Study 2), aimed to investigate the difference between U-15 and U-18 soccer players in speed, change of direction (COD) and power performance after undergoing eight weeks of complex training (CT). Chapter 5 (Study 3), further explored differences between the CT groups and control group in speed, COD and power performance following an eight-week intervention. Additionally, Chapter 1 and 2 provided insights suggesting that chronological age may influence performance outcomes, training effects further justifying these findings.

Study 3, CT had shown to be a great method to improve speed, COD and power performances which all 3 components have significant effects after underwent 8 weeks of CT. But in term of differences between the two studied groups, both Study 2 and 3 had some limitations caused the results did not have significant differences. In future study, future study should to minimize the limitations as in current study to generate more substantial and concrete evidence in trying to find differences between two groups. Generally both Study 2 and 5 need bigger sample size and longer duration of training which 8 weeks of CT in the current was not enough to indicate any differences between the two groups.

In modern soccer, the game's evolving demands necessitate highly specialized and age-appropriate physical training programs especially in youth players. As the sport becomes increasingly competitive and highly demand in technical and tactical aspects, the physical requirements and demands must be met in all aspects of physical components especially for youth soccer players, who are still developing both physically and technically, it is crucial to implement training regimens that are tailored to their developmental stage. Complex training (CT), which integrates various physical and technical components, has been shown to improve specific fitness attributes essential for soccer performance. This approach not only improves overall athletic capability but also helps in injury prevention by ensuring that players develop balanced and well-rounded physical abilities.

By utilizing training programs that align with the demands of modern soccer, coaches and trainers could properly prepare young athletes to meet the physical demands of the game. This not only contributes to their acute performance effects but also supports their long-term development and progression in the sport. Thus, specific and age-appropriate physical training program is crucial for optimizing the potential of youth soccer players and ensuring their success on the field.

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APPENDICES

APPENDIX 1

Health Screening and Assent Form

SECTION A
PERSONAL DETAIL

NO.	PERSONAL INFORMATION	
1	Name	:
2	IC. Number	:
3	Age	:
4	Address	:
5	Position	:
6	Height	:
7	Weight	:

SECTION B

PAR-Q (PHYSICAL ACTIVITY READINESS QUESTIONNAIRE)

Please read the question carefully and answer each one honestly: check yes/ no

NO.		YES	NO
1.	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?		
2.	Do you feel pain in your chest when you do physical activity?		
3.	In the past month, have you had chest pain when you were not doing physical activity?		
4.	Do you lose your balance because of dizziness or do you ever lose consciousness?		
5.	Do you have a bone or joint problem (for example, back knee or hip) that could be made worse by a change in your physical activity?		
6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?		
7.	Do you know of any other reason why you should not do physical activity?		
8.	Have you had any lower extremity injury that has limited your physical activity during the past 6 months?		

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q ad which questions you answered YES.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.

- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonable sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.

- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or

- If you are or may be pregnant – talk to your doctor before you start becoming more active.

Please note: if your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

SECTION C
INFORMED CONSENT FORM

Consent Form

To become a participant in the research, you or your legal guardian is advised to sign this Consent Form.

I herewith confirm that I have met the requirement of age and am capable of acting on behalf of myself /* as a legal guardian as follows:
1. I understand the nature and scope of the research being undertaken.
2. I have read and understood all the terms and conditions of my participation in the research.
3. All my questions relating to this research and my participation therein have been answered to my satisfaction.
4. I voluntarily agree to take part in this research, to follow the study procedures and to provide all necessary information to the investigators as requested.
5. I may at any time choose to withdraw from this research without giving reasons.
6. I have received a copy of the Subjects Information Sheet and Consent Form.
7. Except for damages resulting from negligent or malicious conduct of the researcher(s), I hereby release and discharge UiTM and all participating researchers from all liability associated with, arising out of, or related to my participation and agree to hold them harmless from any harm or loss that may be incurred by me due to my participation in the research.

Name of Participant/Legal Guardian　　　　Signature

I.C No

Date

Name of Witness

Signature

I.C No

Date

Name of Consent Taker

Signature

I.C No

Date

APPENDIX 2

Ethic Approval Letter

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UNIVERSITI TEKNOLOGI MARA

Pejabat
Timbalan Naib Canselor
(Penyelidikan dan Inovasi)

Reference : 600-TNCPI (5/1/6)
Our reference : REC/10/2022 (PG/MR/245)
Date : 20 October 2022

Dr Raihana binti Sharir
(Muhammad Iftiqar bin Ahmad Termizi – 2020547241)
Faculty of Sports Science and Recreation
Academic Building 3,
Universiti Teknologi MARA,
40450 Shah Alam,
SELANGOR

Dear Dr Raihana,

APPROVAL LETTER - UiTM RESEARCH ETHICS COMMITTEE

Thank you for submitting your research proposal to the Research Ethics Committee (REC). After considering your application, the Committee approved your proposal titled "Effects of Complex Training on Speed, Change of Direction and Explosive Power in U-15 and U-18 Soccer Players" at SMK Sultan Idris Shah II, Gerik, Perak.

Details of the approval are as follows:

Ref. number:	REC/10/2022 (PG/MR/245)
Approval Period:	20 October 2022 until 31 January 2023
Authorised personnel:	1. Dr Raihana binti Sharir 2. Assoc. Prof. Dr Raja Mohammed Firhad bin Raja Azidin 3. Muhammad Iftiqar bin Ahmad Termizi

The UiTM Research Ethics Committee operates in accordance to the ICH Good Clinical Practice Guidelines, Malaysian Good Clinical Practice Guidelines and the Declaration of Helsinki. The approval of this project is conditional upon your continuing compliance with these guidelines and declaration.

We draw to your attention the requirement that a report on this research, must be submitted every 12 months from the date of the approval or on the completion of the project, whichever occurs first. Failure to submit reports will result in withdrawal of consent for the project to proceed. Amendments, if any, to the study documents are to be submitted to the REC for approval.

If you require further information, please contact the REC Secretariat at 03-55448069/03-55442794 or email at recsecretariat@uitm.edu.my.

Yours sincerely,

EMERITUS PROFESSOR DATO' DR RAYMOND AZMAN ALI
Chairman
UiTM Research Ethics Committee

c.c.: Dean, Faculty of Sports Science and Recreation, UiTM

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AUTHOR'S PROFILE

Muhammad Iftiqar Ahmad Termizi obtained Bachelor of Sport Science (Hons.) in 2018 from Universiti Teknologi Mara, Seremban, Negeri Sembilan. Before this, he worked as Strength and Conditioning Coach for several team such as PKNP Fc (Youth Cup), Hanelang Fc (FAM Cup), Selangor United Fc (Piala FAM, President Cup, Challenge Cup and Liga Perdana Malaysia). After finished contract, author was accepted to pursue in Program Diploma Pascasiswazah Pendidikan (PDPP) at Institut Pendidikan Guru (IPG) Sultan Abdul Halim Sungai Petani, Kedah which at the same time underwent Master in Science (Sport Science and Recreation) at Universiti Teknologi Mara (UiTM) Shah Alam, Selangor. Currently he is working as a teacher major in Pendidikan Jasmani and Kesihatan and works at Gerik, Perak. The author involved directly in MSSM Perak preparation team every year which held same role as before which was Strength and Conditioning Coach.

LIST OF PUBLICATION

Termizi, M. I. A., Azidin, R. M. F. R., & Sharir, R. (2024). Chronological age and performance differences: A comparative analysis of speed, change of direction and explosive power amongst U-15 and U-18 soccer players. Malaysian Journal of Movement Health & Exercise, 13(2), 83–90. https://doi.org/10.4103/mohe.mohe_11_24

Termizi, M. I. A., Azidin, R. M. F. R., & Sharir, R. (in-review). Optimizing Athletic Abilities: Exploring the Effects of Complex Training on Speed, Change of Direction and Explosive Power in Youth Soccer players. Proceedings of

the 10th Asian Society of Sport Biomechanics Conference and 3rd International Conference on Innovation and Technology in Sports, ASSB-ICITS 2024, 13-15 December 2024, Malaysia: Innovation and Technology in Sports. Springer Nature.

LIST OF ORAL PRESENTATION

i. (30th July - 3rd August 2023). Performance Differences Among U-15 And U-18 Soccer Players: A Study of Speed, Change of Direction and Explosive Power. XXIX Congress of International Society of Biomechanics (ISB) and XXIX Congress of Japanese Society of Biomechanics (JSB)Fukuoka International Congress Center, Fukuoka, Japan.
ii. (18th-20th September 2024). Effects of Complex Training on Speed, Change of Direction and Explosive Power in Youth Soccer Players. The 10th ACPES International Conference Univerisiti Teknologi Mara (UiTM) Shah Alam, Selangor, Malaysia.
iii. (13th-15th December 2024). Optimizing Athletic Abilities: Exploring The Effects of Complex Training on Speed, Change of Direction and Explosive Power in Youth Soccer Players. 10th Asian Society of Sports Biomechanics Conference (ASSB) and 3rd International Conference on Innovation & Technology in Sports (ICITS), Institut Sukan Negara (ISN), Bukit Jalil, Kompleks Sukan Bukit Jalil, Kuala Lumpur, Malaysia.