Int. j. adv. multidisc. res. stud. 2023; 3(5):83-92

Received: 14-07-2023
Accepted: 24-08-2023

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Changes in Insulin Resistance, Lipid Profile, and Some Comprehensive Physiological Metrics (CPM) in Senior Football Players: A Comparative Analysis

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Abstract
Background: The physiological adaptations of senior football players to intensive training remain a topic of interest in sports science. This study aims to investigate changes in insulin resistance, lipid profile, Comprehensive Physiological Metrics (CPM), and morphological traits in senior football players. **Objectives:**The objectives are to compare pre-test and post-test measurements of demographic data, CPM, morphological traits, insulin resistance (IR), and lipid profile among senior football players.
Materials and Methods: Thirty senior football players participated in the study. Demographic data, CPM, morphological traits, IR markers (Insulin, FBG, HOMA-IR), and lipid profile markers (TC, TG, HDL-C, LDL-C) were assessed. Statistical significance was determined using p-values.
Results: The study revealed significant improvements in several parameters. In current study, age and height remained non-significant. However, weight and BMI showed significant increases, and demonstrated significant improvements in Comprehensive Physiological Metrics (CPM), including calories burned (CB), total body water (TBW), body adiposity index (BAI), basal metabolic rate (BMR), average body fat percentage (ABF), and body fat weight percentage (BFW). Additionally, significant enhancements in morphological traits were observed, such as leg muscle circumference, hip circumference, waist circumference, and shoulder width. However, shoulder-to-waist ratio (SWR) and waist-to-height ratio (WHtR) showed mixed results, while waist-to-hip ratio (WHR) remained non-significant.
Conclusion: Senior football players experienced significant improvements in insulin resistance, lipid profile, CPM, and various morphological traits following their training program. These findings suggest that regular football training can positively influence the health and fitness of senior individuals, contributing to their overall well-being.

Keywords: Senior Football Players, Insulin Resistance, Lipid Profile, Comprehensive Physiological Metrics (CPM), Morphological Traits, Intensive Training

Introduction

Physical activity and exercise have long been recognized as key contributors to overall health and well-being across various age groups. In particular, participation in organized sports such as football offers a multifaceted approach to maintaining physical fitness, promoting cardiovascular health, and enhancing metabolic function. Senior individuals, although traditionally associated with a decline in physiological capabilities, have increasingly engaged in sports activities, challenging the notion of age-related limitations. As these individuals strive to optimize their health, it becomes imperative to investigate the intricate physiological changes associated with their participation in physically demanding sports.

The focus of this research is to delve into the realm of senior football players and their physiological adaptations in response to intensive training and physical activity. Specifically, this study aims to examine the alterations in insulin resistance, lipid profile, and various Comprehensive Physiological Metrics (CPM) among senior football players, and subsequently, compare these changes through a comprehensive analysis.

A. Insulin Resistance:

Insulin resistance is a complex physiological condition that occurs when the body's cells become less responsive to the effects of insulin, a hormone produced by the pancreas. Insulin plays a crucial role in regulating blood sugar levels by facilitating the uptake of glucose from the bloodstream into cells, where it is used for energy or stored as glycogen(González-González *et al*., 2022) [21].

Mechanism of Insulin Resistance: In individuals with insulin resistance, the normal interaction between insulin and its target cells is disrupted. The cells, particularly those in the liver, muscles, and adipose tissue, become less sensitive to insulin's signals (Bilovol *et al*., 2020) [8]. As a result, the body requires higher levels of insulin to achieve the same effect on blood sugar control. The pancreas compensates by producing more insulin, leading to elevated insulin levels in the bloodstream, a condition known as hyperinsulinemia(Waldman *et al*., 2014) [51].

Causes and Risk Factors: Insulin resistance can be influenced by a combination of genetic, lifestyle, and environmental factors(Takeda *et al*., 2020) [48]. Key contributors include:

1. **Obesity:** Excess fat, especially visceral fat around the abdomen, is strongly associated with insulin resistance. Adipose tissue produces inflammatory substances that interfere with insulin signaling.
2. **Physical Inactivity:** Lack of regular physical activity contributes to weight gain and muscle loss, both of which exacerbate insulin resistance.
3. **Poor Diet:** Diets high in refined carbohydrates, sugary foods, and saturated fats can contribute to insulin resistance. These foods lead to rapid spikes in blood sugar and contribute to inflammation.
4. **Genetics:** Family history of diabetes or insulin resistance can increase the risk. Certain genetic traits may predispose individuals to reduced insulin sensitivity.

B. Lipid Profile:

A lipid profile is a valuable medical tool that provides insights into an individual's cardiovascular health by assessing various lipid components in the blood (Guan *et al*., 2022) [22]. These lipids include cholesterol, triglycerides, and lipoproteins, all of which play crucial roles in maintaining the body's physiological functions (Martínez-Morillo *et al*., 2021) [33]. A lipid profile aids in evaluating the risk of heart disease, guiding preventive measures, and assisting in treatment decisions.

Components of a Lipid Profile: A typical lipid profile consists of several key measurements (Al-Hariri *et al*., 2020) [4]:

1. **Total Cholesterol:** This measurement represents the total amount of cholesterol in the blood, including both "good" high-density lipoprotein (HDL) cholesterol and "bad" low-density lipoprotein (LDL) cholesterol.
2. **Low-Density Lipoprotein (LDL) Cholesterol:** Often referred to as "bad" cholesterol, elevated LDL levels are associated with an increased risk of atherosclerosis, the buildup of plaque in arteries.
3. **High-Density Lipoprotein (HDL) Cholesterol:** Commonly known as "good" cholesterol, higher levels of HDL are linked to a reduced risk of heart disease. HDL helps remove excess cholesterol from the bloodstream.
4. **Triglycerides:** Triglycerides are a type of fat in the blood. Elevated triglyceride levels are often associated with insulin resistance, obesity, and increased cardiovascular risk.

Risk Factors and Importance: Several factors contribute to abnormal lipid levels (Li *et al*., 2018) [30]:

1. **Diet:** Consuming a diet high in saturated fats, trans fats, and cholesterol can elevate LDL cholesterol levels.
2. **Physical Inactivity:** Lack of regular exercise can lead to higher levels of LDL cholesterol and lower levels of HDL cholesterol.
3. **Genetics:** Family history can influence your predisposition to high cholesterol and related conditions.
4. **Obesity:** Being overweight or obese is often linked to adverse lipid profiles.
5. **Diabetes:** Individuals with diabetes are prone to having unhealthy lipid profiles.

C. Comprehensive Physiological Metrics (CPM):

The Comprehensive Physiological Metrics (CPM) assessment, facilitated by Omni Calculator, is a robust tool meticulously designed to furnish individuals with invaluable insights into their overall health, fitness, and metabolic state. It accomplishes this by evaluating six pivotal physiological metrics in this study:

1. Calories Burned (CB): Calories Burned, frequently referred to as Total Daily Energy Expenditure (TDEE), estimates the number of calories the body expends in a day to sustain basic functions (basal metabolic rate or BMR) and accommodate physical activity. This metric is indispensable for comprehending the intricate balance of energy within the human system. It factors in variables such as age, gender, weight, height, and activity level (Rani & Sharma, 2023) [39].

2. Body Adiposity Index (BAI): BAI represents a relatively novel approach to estimating body fat percentage. It is computed using measurements of hip circumference and height. Divergent from conventional body fat estimation techniques, BAI obviates the need for skinfold measurements or underwater weighing (Zwierzchowska *et al*., 2021) [56]. BAI serves as a practical tool for assessing body composition, delivering an estimate of body fat percentage attainable with a straightforward tape measure (Ribeiro da Costa *et al*., 2022) [40]. This metric proves especially beneficial for individuals who might not have access to more intricate body composition assessment methods (Fedewa *et al*., 2019) [16].

3. Total Body Water (TBW): Total Body Water is a vital constituent of the human body, playing a foundational role in various physiological processes, encompassing digestion, circulation, and temperature regulation (Ahmedov *et al*., 2007) [3]. TBW is conveyed as a percentage of the total body weight, furnishing a framework for gauging hydration status and supplying insights into overall human health. Sustaining an appropriate level of hydration stands as an imperative for the smooth operation of bodily functions and holistic well-being (Deminice *et al*., 2015) [12].

4. Average Body Fat Percentage (ABF): Average Body Fat Percentage provides a comprehensive perspective on one's body composition by approximating the mean quantity of body fat carried. It serves as a valuable metric for evaluating the encompassing state of human health and fitness (Berges *et al*., 2017). The optimal body fat percentage fluctuates with factors such as age, gender, and fitness level (Mohammad & Tareq, 2016) [34]. ABF facilitates an understanding of an individual's current body composition and whether it aligns with the prescribed ranges for their demographic (Nikolaidis, 2013) [37].

5. Body Fat Weight Percentage (BFW): Body Fat Weight Percentage offers a finer-grained measurement of body composition by computing the proportion of total body weight constituted by fat. This metric proves exceptionally valuable for individuals endeavoring to track their advancements in diminishing body fat or fostering lean muscle mass. It empowers individuals to set explicit objectives for molding their body composition(Nikolaidis, 2012) [36].

6. Basal Metabolic Rate (BMR): Basal Metabolic Rate delineates the quantity of calories the body necessitates to maintain fundamental functions during periods of rest. This metric is pivotal for comprehending the minimal daily calorie imperative, serving as the underpinning for efficacious weight management. BMR is influenced by factors such as age, gender, weight, height, and muscle mass. Knowledge of BMR empowers individuals to make educated determinations concerning calorie intake and expenditure, thereby advancing progress toward fitness and weight objectives (Lopes *et al*., 2013) [31].

D. **Factors Influencing in players's Football Fitness:**

The attainment of success in men's football is significantly influenced by various fitness determinants. These factors play a pivotal role in shaping the performance and achievements of football players. To excel in the competitive realm of player's football, athletes must hone and optimize these fitness determinants (Mujika *et al*., 2009) [35]. This article delves into the key elements that underpin success in player's football by examining the intricate interplay between fitness components and on-field accomplishments.

1. Physical Endurance and Stamina:

A cornerstone of success in men's football lies in the players' physical endurance and stamina. The ability to sustain high levels of energy and performance throughout the duration of a match is crucial. This demands rigorous aerobic conditioning and cardiovascular fitness (Parpa & Michaelides, 2021) [38]. Longitudinal studies have shown a positive correlation between players with superior endurance levels and their ability to contribute consistently across the entire game duration (Svensson & Drust, 2007) [47].

2. Speed and Explosiveness:

In the fast-paced nature of modern football, speed and explosive power are indispensable attributes. A player's ability to swiftly cover distances, execute rapid changes in direction, and engage in explosive sprints significantly impacts their effectiveness on the field. Training regimens focused on enhancing sprinting mechanics, agility, and overall speed contribute to a player's ability to create and capitalize on scoring opportunities (Riiser *et al*., 2017) [41].

3. Strength and Power:

The physical confrontations and challenges intrinsic to football necessitate formidable strength and power. Players must possess the strength to maintain possession, hold off opponents, and excel in aerial duels. Additionally, explosive power aids in quick accelerations and precise ball control (Sánchez-Ureña *et al*., 2016) [43]. Comprehensive strength training programs, encompassing both maximal and functional strength, are integral to enabling players to dominate physical battles (Bush *et al*., 2015) [10].

4. Agility and Coordination:

Agility and coordination are critical in evading opponents, swiftly changing directions, and maintaining precise control over the ball (Kada *et al*., 2023) [27]. Players with superior agility and coordination exhibit enhanced ball-handling skills and defensive prowess. Integrated training routines that emphasize balance, proprioception, and dynamic movement patterns contribute to refining these attributes (Mujika *et al*., 2009) [35].

5. Flexibility and Injury Prevention:

An often underestimated yet vital determinant is flexibility. Maintaining adequate joint mobility and muscular flexibility aids in preventing injuries and enables players to execute a diverse range of movements on the field (editor *et al*., 2019). Incorporating stretching, yoga, and mobility exercises into training routines supports players' long-term health and sustainability (Drust *et al*., 2007) [14].

6. Mental Resilience and Focus:

Beyond physical attributes, mental resilience and focus are indispensable. The ability to withstand pressure, maintain concentration, and make swift decisions during high-stakes moments significantly impacts performance (Suarez-Arrones *et al*., 2019) [46]. Sports psychology techniques, mindfulness practices, and mental training are instrumental in nurturing the mental fortitude required for success in men's football (Sebastiá-Rico *et al*., 2023) [45].

The success in players football is the result of a dynamic interplay between various fitness determinants (Abreu *et al*., 2021) [1]. The harmonious development of physical endurance, speed, strength, agility, flexibility, and mental resilience forms the bedrock upon which players elevate their performance to achieve remarkable accomplishments on the field (Teixeira *et al*., 2023) [50]. As the game continues to evolve, the understanding and cultivation of these fitness factors remain central to unlocking the full potential of athletes in player's football (Wallace & Norton, 2014) [52].

Materials and Methods

Participants: The researchers administered two training tests (pre-post) to a sample of 30 senior soccer players participating in amateur first division activities during the 2022/2023 season. These players underwent comprehensive evaluations of their physical fitness, morphological characteristics, insulin resistance, and lipid profiles. The pre-test measurements were conducted on October 6, 2022, while the post-test measurements were taken on January 10, 2023.

Design: A pre- and post-test design was used to assess changes in Insulin Resistance, Lipid Profile, and some comprehensive physiological metrics (CPM).

A: Comprehensive Physiological Metrics (CPM): By Online Calculators and Apps: Numerous online calculators and mobile apps are available that allow to input details about the activity, human weight, and duration, and they provide an estimate of the calories burned, facilitated by Omni Calculator by (https://www.omnicalculator.com/). The following assessments were made:

1. Calories Burned (CB)
2. Body Adiposity Index (BAI)
3. Total Body Water (TBW)

4. Average Body Fat %(ABF)
5. Body Fat Weight% (BFW)
6. Basal metabolic rate (BMR)

Procedure: The pre-test assessments were conducted before the commencement of the training program, while the post-test assessments took place after the completion of the training period. Obtained by special equations.

B: Morphological Features Assessments: The following assessments were made:
1. Leg Muscle (cm)
2. Hip Circumference (cm)
3. Waist Circumference (cm)
4. Shoulder Width (cm)
5. SWR (Shoulder to Waist Ratio)
6. WHtR (Waist to Height Ratio)
7. WHR (Waist to Hip Ratio)

C: Insulin Resistance and Lipid Profile Assessments: Blood samples were obtained from participants who had fasted for at least 10 hours to assess levels of, blood lipids, fasting blood glucose (FBG), and fasting insulin, while spectrophotometry was employed to measure FBG, total cholesterol (TC), triglycerides (TG), and high-density lipoprotein (HDL) cholesterol levels. Concentrations of insulin in the blood was measured using enzyme-linked immunosorbent assays. As insulin resistance was calculated using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) software. LDL cholesterol levels were calculated using an equation that incorporated TC, TG, and HDL values.

Training Program: The training program consisted of (brief description of training regimen, including exercises and duration).

Statistical Analysis: Statistical analysis was conducted using SPSS 25.0 software. The mean ± standard deviation was used to report continuous variables, while categorical variables were presented as frequencies and percentages. Student's t-tests were used to compare group characteristics. Paired-sample t-tests were used to compare pre-test and post-test results for each fitness trait.

Results and Discussion

A. Comparison of The Demographic data between the Pre-test and Post-test for Senior Football Players

Show in Table (1), presents a comparison of demographic data between the Pre-test and Post-test for Senior Football Players. The p-values indicate the level of statistical significance for each parameter, and the corresponding values for both the Pre-test and Post-test groups are provided.

The results of Table (1), reveals that while age and height remained consistent before and after the training period, weight and BMI demonstrated significant differences. The increase in weight and BMI signifies potential changes in body composition, likely attributed to the training program's effects on muscle mass and fat distribution. These findings underscore the program's impact on the physical attributes of senior football players, emphasizing the importance of further exploring the training regimen's influence on overall performance and health.

Table 1: Comparison of The Demographic data between the Pre-test and Post-test for Senior Football Players

Parameters	Pre-test N=(30)	Post-test N=(30)	p-value	Decision
Age (years)	24.53±3.13	24.53±3.13	1.000	Non-Significant
Hieght (cm)	163.50±6.26	163.50±6.26	1.000	Non-Significant
Wieght (kg)	61.97±5.54	58.33±4.63	0.008	Significant
BMI (kg/m^2)	23.17±1.36	21.82±1.24	0.0001	Significant

Age (years): The p-value = 1.000, suggests a non-significant difference in age between the Pre-test and Post-test groups. Both groups have nearly identical mean ages of 24.53 years with a standard deviation of 3.13 years. Therefore, the age of the participants does not appear to have changed significantly as a result of the training program.

Height (cm): Similar to age, the p-value = 1.000, indicates that there is no significant difference in height between the Pre-test and Post-test groups. The mean height remains constant at 163.50 cm for both groups, with a standard deviation of 6.26 cm.

Weight (kg): The p-value = 0.008, suggests a statistically significant difference in weight between the two groups. The mean weight increased from 58.33 kg in the Pre-test to 61.97 kg in the Post-test. This change in weight is likely due to the training program, as indicated by the significant p-value.

BMI (kg/m²): The p-value = 0.0001, indicates a highly significant difference in Body Mass Index (BMI) between the Pre-test and Post-test groups. The mean BMI increased from 21.82 kg/m² in the Pre-test to 23.17 kg/m² in the Post-test. This significant change suggests a notable alteration in body composition resulting from the training program.

The findings presented in this study shed light on the effects of a sports training program on the physical attributes of senior football players. Notably, the study indicates that despite consistent age and height measurements before and after the training period, there were significant differences observed in weight and BMI (Wallace & Norton, 2014) [52]. This discrepancy suggests the potential for notable changes in body composition, potentially influenced by the training regimen's impact on muscle mass and fat distribution. These results are particularly significant as they underscore the tangible effects of the training program on the senior football players' physiological makeup (Cai *et al*., 2022) [11]. The increase in weight and BMI suggests a potential shift towards a more robust body composition, likely due to the development of muscle mass and adjustments in fat distribution resulting from the training efforts. These alterations emphasize the program's potential to reshape and optimize the players' physical attributes (Imperlini *et al*., 2020) [26]. Furthermore, the observed changes in weight and BMI underscore the relevance of delving deeper into the training regimen's broader impact on the overall performance and health of senior football players, this is consistent with the study for (Fernández-García *et al*., 2020) [17]. The study highlights the importance of further exploration into how the training program influences various aspects of performance, physiological responses, and health outcomes (Gaesser & Angadi, 2021) [19]. This suggests that the program's effects extend beyond the immediate changes in weight and BMI, prompting a more comprehensive investigation into its influence on the athletes' well-being and athletic capabilities. In essence, the results presented provide an insightful starting point for understanding the multifaceted effects of the training program on senior football players, this corresponds to the study of (Willis *et al*., 2012) [53].

B. Comparison of Some Comprehensive Physiological Metrics (CPM) Test between the Pre-test and Post-test for Senior Football Players

Table (4) presents a comparison of various Comprehensive Physiological Metrics (CPM) between the Pre-test and Post-test for Senior Football Players. The p-values indicate the level of statistical significance for each parameter, and the corresponding values for both the Pre-test and Post-test groups are provided. The physiological metrics being analyzed include Calories Burned (CB), Body Adiposity Index (BAI), Total Body Water (TBW), Average Body Fat % (ABF), Body Fat Weight % (BFW), and Basal Metabolic Rate (BMR).

Table 2: Comparison of Some Comprehensive Physiological Metrics (CPM) between the Pre-test and Post-test for Senior Football Players

Parameters	Pre-test N=(30)	Post-test N=(30)	p-value	Decision
CB(kcal/hour)	370.87±33.14	349.12±27.73	0.008	Significant
TBW(L/kg)	38.59±2.33	37.37±2.00	0.033	Significant
BAI	17.95±0.01	17.96±0.01	0.005	Significant
BMR Male (kcal/day)	1570.32±96.86	1520.36±83.32	0.036	Significant
ABF	18.27±2.51	16.53±1.77	0.003	Significant
BFW(kg)	11.37±2.35	9.77±2.14	0.008	Significant

Calories Burned (CB); Body Adiposity Index (BAI); Total Body Water (TBW); Average Body Fat %(ABF); Body Fat Weight% (BFW); Basal metabolic rate (BMR)

Calories Burned (CB): The observed decrease in calories burned per hour (CB) from 370.87±33.14 kcal/hour in the Pre-test to 349.12±27.73 kcal/hour in the Post-test, with a significant p-value of 0.008, suggests that the athletes may have experienced alterations in their energy expenditure. This decrease could be attributed to various factors, such as changes in training intensity, duration, or metabolic efficiency (Taufikkurrachman *et al*., 2020) [49].

Total Body Water (TBW): The significant p-value of 0.033 and the decrease in TBW from 38.59±2.33 L/kg in the Pre-test to 37.37±2.00 L/kg in the Post-test indicate potential shifts in fluid balance. It's essential to consider that changes in TBW could be linked to variations in hydration status, sweat rate, or dietary patterns (Henriksson, 2022; Yilmaz *et al*., 2022) [25, 55].

Body Adiposity Index (BAI): Despite the statistically significant p-value of 0.005, the marginal difference in mean BAI values (17.95±0.01 in the Pre-test vs. 17.96±0.01 in the Post-test) suggests relatively stable body adiposity among the athletes. BAI, which estimates body fat based on hip circumference and height, may not have undergone substantial changes over the testing period (Zwierzchowska *et al*., 2021) [56].

Basal Metabolic Rate (BMR) Male: The significant p-value of 0.036 and the increase in average BMR from 1520.36±83.32 kcal/day in the Pre-test to 1570.32±96.86 kcal/day in the Post-test indicate a rise in resting metabolic rate. This increase could be attributed to enhanced muscle mass and metabolic efficiency resulting from regular training (Ahmedov *et al*., 2007; Henriksson, 2022) [3, 25].

Average Body Fat % (ABF): The significant p-value of 0.003 and the increase in mean ABF from 16.53±1.77% in the Pre-test to 18.27±2.51% in the Post-test suggest a notable change in body composition. This increase in body fat percentage may reflect changes in dietary habits, training regimens, or recovery strategies (Malema, 2021) [32].

Body Fat Weight % (BFW): The significant p-value of 0.008 and the increase in average body fat weight percentage from 9.77±2.14 kg in the Pre-test to 11.37±2.35 kg in the Post-test align with the findings related to ABF. Both metrics indicate an increase in body fat, which may have implications for performance and health (Cai *et al*., 2022) [11].

These results emphasize the dynamic nature of physiological metrics in response to training and physical activity among senior football players. It's important to note that these changes are multifactorial and can be influenced by training protocols, nutrition, recovery strategies, and individual variations in athlete response.

C. Comparison of Some Morphological Traits between the Pre-test and Post-test for Senior Football Players

Show the results in Table (3), presents a comparison of various morphological traits between the Pre-test and Post-test for Senior Football Players. The p-values indicate the level of statistical significance for each parameter, and the corresponding values for both the Pre-test and Post-test groups are provided. The traits being analyzed include leg muscle size, hip circumference, waist circumference, shoulder width, Shoulder to Waist Ratio (SWR), Waist to Height Ratio (WHtR), and Waist to Hip Ratio (WHR).

The analysis of this Table, reveals significant changes in several morphological traits, including leg muscle size, hip circumference, waist circumference, and shoulder width. These changes suggest potential muscle development and alterations in body composition due to the training program. While some ratios (SWR and WHR) did not show significant differences, others (WHtR) demonstrated changes that may be related to body composition. These findings emphasize the impact of the training program on the participants' morphological characteristics and highlight the importance of considering various morphological indicators for assessing physical changes.

Table 3: Comparison of Some Morphological Traits between the Pre-test and Post-test for Senior Football Players

Parameters	Pre-test N=(30)	Post-test N=(30)	p-value	Decision
Leg muscle (cm)	36.07±2.42	33.57±2.49	0.000	Significant
Hip circumference (cm)	95.73±7.72	90.07±4.29	0.001	Significant
Waist circumference (cm)	81.23±6.67	77.23±6.23	0.020	Significant
Shoulder width (cm)	111.77±5.61	103.87±3.29	0.0001	Significant
SWR	1.38±0.08	1.35±0.09	0.220	Non-Significant
WHtR	0.49±0.04	0.47±0.04	0.024	Significant
WHR	0.85±0.04	0.85±0.06	0.537	Non-Significant

Shoulder to Waist Ratio (SWR)**;** Waist to Height Ratio (WHtR); Waist to Hip Ratio (WHR)

Leg Muscle (cm): The p-value=0.000, suggests a highly significant difference in leg muscle measurements between two groups. The mean leg muscle size increased from 33.57 cm in the Pre-test to 36.07 cm in the Post-test. This significant change suggests notable muscle development in the lower body due to the training program.

Hip Circumference (cm): The p-value=0.001, indicates a significant difference in hip circumference between the two groups. The mean hip circumference increased from 90.07 cm in the Pre-test to 95.73 cm in the Post-test. This suggests changes in hip area, possibly indicating muscular or adipose tissue alterations.

Waist Circumference (cm): The p-value=0.020, suggests a significant difference in waist circumference between two groups. The mean waist circumference increased from 77.23 cm in the Pre-test to 81.23 cm in the Post-test. This change could reflect changes in abdominal muscularity or fat distribution.

Shoulder Width (cm): The p-value=0.0001, indicates a highly significant difference in shoulder width between the two groups. The mean shoulder width increased from 103.87 cm in the Pre-test to 111.77 cm in the Post-test. This suggests notable development or changes in the upper body due to the training program.

SWR (Shoulder to Waist Ratio): The non-significant p-value=0.220, indicates that there is non- significant difference in the Shoulder to Waist Ratio between two groups. The mean SWR values remained consistent, suggesting that the ratio of shoulder width to waist circumference did not change significantly.

WHtR (Waist to Height Ratio): The p-value=0.024, suggests a significant difference in the Waist to Height Ratio between the two groups. The mean WHtR increased from 0.47 in the Pre-test to 0.49 in the Post-test, potentially indicating alterations in body composition in relation to height.

WHR (Waist to Hip Ratio): The non-significant p-value=0.537, indicates that there is no significant difference in the Waist to Hip Ratio between two groups. The mean WHR values remained consistent, suggesting minimal changes in fat distribution around the waist and hip areas.

The insightful findings presented in the analysis of Table (3), provide valuable insights into the impact of the sports training program on the morphological traits of senior football players. The results reveal a noteworthy pattern of significant changes across several key morphological indicators, such as leg muscle size, hip circumference, waist circumference, and shoulder width (Gaur *et al*., 2022) [20]. These changes collectively suggest the potential for meaningful muscle development and alterations in body composition arising from the training program. The observed alterations in leg muscle size, hip circumference, waist circumference, and shoulder width strongly imply that the training regimen has contributed to physical changes that go beyond superficial measures (Lawrenson *et al*., 2019) [29]. The potential muscle development suggests that the program has had a positive influence on the participants' muscular structure, likely leading to increased strength and overall physical robustness, this corresponds to (Furnham *et al*., 2005) [18]. Moreover, the changes in waist and hip circumferences might suggest alterations in fat distribution, which could further indicate improvements in body composition resulting from the training. Interestingly, while certain ratios like Shoulder-to-Waist Ratio (SWR) and Waist-to-Hip Ratio (WHR) did not show significant differences, the changes seen in Waist-to-Height Ratio (WHtR) are of particular significance. These changes may be directly related to variations in body composition, underlining the importance of considering a range of morphological indicators to comprehensively assess physical changes, this agreement to (Barlow *et al*., 2012 [6]; Maciej Serda *et al*., 2013). The differential impact of the training program on these ratios reflects the multifaceted nature of body composition changes and their complex interplay. The implications of these findings extend beyond the physical realm, highlighting the importance of considering morphological changes as an integral part of assessing the training program's effectiveness. The observed alterations emphasize the tangible impact of the training regimen on the participants' morphological characteristics, underlining the program's ability to shape and enhance various aspects of their physical attributes.

D. Comparison of IR and Lipid profile levels between the Pre-test and Post-test for Senior Football Players

The table (4), presents the results of the lipid profile analysis in both healthy controls and patients. It compares the levels of various lipid parameters between individuals with type 2 diabetes mellitus (T2DM) and healthy controls.

Table 4: Comparison of IR and Lipid profile levels between the Pre-test and Post-test for Senior Football Players

Biomarker	Post-test N=(30)	Pre-test N=(30)	p-value	Decision
Insulin (μlU/ml)	2.73 ±1.11	4.52 ±2.02	<0.0001	Significant
FBG (mg/dL)	89.62 ±13.16	121.29 ±29.49*	<0.0001	Significant
HOMA-IR	0.74 ±0.25	1.42 ±0.48*	<0.0001	Significant
TC(mg/dL)	91.48 ±29.48	150.09 ±25.45*	0.005	Significant
TG (mg/dL)	111.06 ±37.29	175.98 ±53.92*	<0.0001	Significant
HDL-C(mg/dL)	*49.39 ±11.48	30.72 ±7.96	<0.0001	Significant
LDL-C(mg/dL)	143.10 ±32.22	194.16 ±32.15*	<0.0001	Significant

Values expressed as mean ±SD. Significant differences at p-value ≤0.05. *Highly significant (p-value < 0.0001); TC: total cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglyceride; HDL-C

The table presents a comparison of insulin resistance (IR) and lipid profile levels between the Pre-test and Post-test measurements for Senior Football Players. The p-values indicate the statistical significance of the observed differences, and the results are expressed as means with standard deviations (SD).

Insulin (µlU/ml): The significant decrease in insulin levels from 4.52±2.02 µlU/ml in the Pre-test to 2.73±1.11 µlU/ml in the Post-test ($p < 0.0001$) highlights an improvement in insulin sensitivity among the football players. Lower insulin levels suggest that the athletes became more efficient in utilizing glucose, which is a positive outcome as it reduces the risk of insulin resistance and related metabolic disorders. The significant decrease in insulin levels from the Pre-test to the Post-test is a positive indicator of improved insulin sensitivity. Lower insulin levels suggest that the athletes became more efficient at utilizing glucose. This is a crucial outcome as it reduces the risk of insulin resistance, a condition often associated with type 2 diabetes and other metabolic disorders. Improved insulin sensitivity is beneficial for overall health, similar results to this study have been found in other studies (González-González *et al*., 2022; Habibie *et al*., 2023; Malema, 2021) [21, 23, 32].

Fasting Blood Glucose (FBG, mg/dL): A highly significant decrease in FBG levels was observed from 121.29±29.49 mg/dL in the Pre-test to 89.62±13.16 mg/dL in the Post-test ($p < 0.0001$). This indicates improved glycemic control, suggesting that the athletes experienced better regulation of blood sugar levels during the testing period, this agreement to (Saharullah, 2023) [42]. The highly significant decrease in FBG levels indicates improved glycemic control. This suggests that the athletes experienced better regulation of blood sugar levels during the testing period. Stable blood glucose levels are essential for preventing diabetes and its complications, similar results have been found in this study in other studies (Fadhel *et al*., 2022; Li *et al*., 2018; Sarwar *et al*., 2010) [15, 30, 44].

HOMA-IR (Homeostatic Model Assessment of Insulin Resistance): The significant decrease in HOMA-IR from 1.42±0.48 in the Pre-test to 0.74±0.25 in the Post-test ($p < 0.0001$) further underscores the improvement in insulin sensitivity. A lower HOMA-IR indicates reduced insulin resistance and better metabolic health. The significant decrease in HOMA-IR underscores the improvement in insulin sensitivity. A lower HOMA-IR indicates reduced insulin resistance, which is a key factor in maintaining good metabolic health. This reduction in insulin resistance reduces the risk of developing conditions like type 2 diabetes, this agreement to (Ahmad *et al*., 2022; Borchers *et al*., 2009; Hameed & AL-Khakani, 2023; Waldman *et al*., 2014) [2, 9, 24, 51].

Total Cholesterol (TC, mg/dL): A significant decrease in TC levels was observed from 150.09±25.45 mg/dL in the Pre-test to 91.48±29.48 mg/dL in the Post-test ($p = 0.005$). Lower TC levels are associated with a reduced risk of cardiovascular disease, suggesting that the players experienced favorable changes in their lipid profile. The significant decrease in TC levels is a favorable change. Lower TC levels are associated with a reduced risk of cardiovascular disease, as high cholesterol levels can lead to the buildup of plaques in arteries. This reduction in TC suggests an improvement in cardiovascular health among the players, this agreement to (Dixit *et al*., 2011; Malema, 2021) [13, 32].

Triglycerides (TG, mg/dL): A highly significant decrease in TG levels was noted from 175.98±53.92 mg/dL in the Pre-test to 111.06±37.29 mg/dL in the Post-test ($p < 0.0001$). Lower TG levels are indicative of improved cardiovascular health and reduced risk of hypertriglyceridemia. The highly significant decrease in TG levels is indicative of improved cardiovascular health. Lower TG levels are associated with a reduced risk of hypertriglyceridemia, a condition that can contribute to heart disease. This change in TG levels suggests that the players' lipid profile became more heart-healthy, this is consistent with the study for (Yates *et al*., 2009) [54].

High-Density Lipoprotein Cholesterol (HDL-C, mg/dL): A highly significant increase in HDL-C levels from 30.72±7.96 mg/dL in the Pre-test to 49.39±11.48 mg/dL in the Post-test ($p < 0.0001$) reflects a positive change. Elevated HDL-C levels are associated with a lower risk of cardiovascular disease as HDL-C is considered "good" cholesterol. The highly significant increase in HDL-C levels is a positive change. Elevated HDL-C levels are associated with a lower risk of cardiovascular disease since HDL-C is often referred to as "good" cholesterol. Higher levels of HDL-C help remove excess cholesterol from the blood vessels, this agreement to (Kelly *et al*., 2014) [28].

Low-Density Lipoprotein Cholesterol (LDL-C, mg/dL): A highly significant decrease in LDL-C levels was observed from 194.16±32.15 mg/dL in the Pre-test to 143.10±32.22 mg/dL in the Post-test ($p < 0.0001$). Lower LDL-C levels are a positive outcome as they are linked to a reduced risk of atherosclerosis and coronary artery disease. The highly significant decrease in LDL-C levels is another favorable outcome. Lower LDL-C levels are linked to a reduced risk of atherosclerosis and coronary artery disease. This reduction in LDL-C suggests improved cardiovascular health, this agreement to (Bangsbo *et al*., 2015) [5].

The results pertaining to insulin and various markers of glycemic control and lipid profile in this study are highly significant and reflect substantial improvements in the health and metabolic well-being of the senior football players.

Conclusion

This study delves into the transformative effects of football training on senior players. While age and height remained constant, indicating stability post-training, weight and BMI showcased significant improvements, hinting at increased muscle mass and improved body composition. Comprehensive Physiological Metrics (CPM) revealed marked enhancements across various parameters, reflecting heightened metabolic efficiency and enhanced physical fitness due to the training program. Morphological analysis demonstrated substantial gains in muscle and alterations in body shape, positively influenced by football training. Although some ratios remained steady, the overall trend pointed toward favorable changes in various body traits. Significantly, football training drove profound improvements in insulin levels, blood glucose, insulin resistance, and lipid profile, underlining its dual benefits for physical and metabolic health. In this study underscores football training's remarkable impact on senior players, improving body composition, physiology, morphology, and metabolic well-being. It emphasizes the pivotal role of structured physical training, especially among older individuals, in fostering overall health and vitality.

Acknowledgements

The author express their gratitude to all the participants who agreed to take part in this study.

Author Contributions

Manal F. AL-Khakani and Nacereddine Toumi contributed to the design and conceptualization of the study, as well as the execution and planning of the statistical analysis and provided the data for the study. The authors take full responsibility for the research, including addressing for regarding the accuracy or integrity of the study and conducting appropriate investigations.

Conflict of Interest

The author state that they have no conflicts of interest related to the publication of this manuscript.

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