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The effect of body composition on match physical performance in highly trained male football players

Extended introduction, previous literature and methods

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Innholdsfortegnelse

Foreword

After two challenging, exciting, and instructive years, I have finally reached the very end of my sports science Master´s thesis. Due to the competent professors and my fellow students, this has been two great years.

First, I would like to thank the players and coaches at Tromsø IL for their enthusiastic participation in this project. I also want to thank UiT – The Arctic University of Norway for the use of lab, equipment and Alfheim stadium. I want to thank Sigurd Pedersen for his help and guidance through the test protocols regarding this project, and Edvard H Sagelv who helped me with the project sketch and the ethical part. They both did not hesitate to help when needed.

Special thanks to my supervisor Andreas Winther, who has been guiding me every step of the way in the best possible manner, helping me to reach the finish line of this project. His guidance, reviews and recommendations has been fundamental factors for this outcome. Working with him, and the other people mentioned above, has been a steep learning curve for me, and has left me more competent and skilled than ever.

1 Introduction

Football is considered one of the most popular sports in the world with billions of supporters and more than 240 million active players worldwide, and is without exception played in every nation (Andersen et al., 2016; Reilly & Williams, 2003). It is practiced on a rectangular field with a goal at each short side, usually on a substrate made of real or artificial grass. During two rounds of 45 minutes separated by a 15-minute break, two teams are using their own preferred strategies to get the same ball in the opposing teams' goal (Şener & Karapolatgil, 2015). The modern game of football with the standardized rules as we know it today has its origin from Great Britain in mid 1800s. Earlier, some violent and disorganized football-like games was played between whole villages, causing kings to actually forbid it (Walvin, 2014).

As well as a fun and social everyday activity for many, it is also a very serious matter for most people. Due to the sport´s sporadic physical demands, a multifaceted physical capacity is essential for a football player to perform a wide range of skills including running, jumping, sprinting, tackles and more. In addition, psychological, tactical and technical skills are needed for a team to achieve superior performance (Dolci et al., 2018). Therefore, we find a striking growth in studies regarding performance enhancement over the last decades, as well as well-educated people working in federations and football clubs around the world (Reilly & Williams, 2003).

In many sports, the athletes´ body composition is highly related to competition-specific tests. For instance, in division 1 men´s hockey athletes, lower BF% is found related to higher skating speeds (Potteiger, Smith, Maier & Foster, 2010). In professional basketball players it is found that lower BF% and greater lean muscle mass (LMM) is related to vertical jumping performance (Ribeiro, Mota, Sampaio-Jorge, Morales & Leite, 2015). In addition, changes in body composition could give information regarding changes in nutritional status or the adaptation to different types of training (Andreoli et al., 2003). Using physical capacity diagnostics is a necessity in a professional teams training process. It offers vital feedback concerning the players´ current fitness level, its increasing or decreasing trend and the readiness for performance (Cipryan & Gajda, 2011). This will also help to monitor eventual osteoporosis or other injuries. Hence, from a hypothetical standpoint, some relationship between body composition and performance should apply to football players as well.

1.1 Issue

This study will deal with body composition and match play performance in football.

As complex as the game of football really is, football players seem to be quite the homogeneous group when it comes to anthropometry and body composition (Calbet, Dorado, Díaz-Herrera & Rodríguez-Rodríguez, 2001; Milanese, Cavedon, Corradini, De Vita & Zancanaro, 2015; Radzimiński, Szwarc, Padrón-Cabo & Jastrzębski, 2020; Silvestre, West, Maresh & Kraemer, 2006; Sutton, Scott, Wallace & Reilly, 2009).

I certainly believe that an optimal proportioned physique would affect different single-player abilities that can help a team to become superior. In addition, knowledge, and equipment to assess body composition could be crucial for rehabilitation, training planning and goal achievement. That is why the aim of this study is to examine the effect of body composition on match performance in highly trained male football players.

2 Previous literature

In professional football teams, measuring the players´ body composition is nearly a normality, but the purpose is mostly related to monitoring the effects of exercise and diet, as well as generalization of typical characteristics in professional football players, and contrasts in different playing positions (Williams, 2013). However, the direct relationship between body composition and physical match performance is relatively modest reviewed (Radzimiński et al., 2020). This chapter will assess literature regarding the physical demands of football, body composition with DXA and position data with ZXY.

Previous literature regarding the physical demands of football mostly concerns endurance, and thus the aerobic and anaerobic energy system. Elite football players maintain an intensity level over 70% of maximal oxygen consumption (VO_2max), where the aerobic energy system is dominating. Anaerobic energy releasing processes is also stimulated during highly intensive actions as sprinting, jumping, tackling and turns by a reproduction of creatine phosphate during a period of low intensity, and simultaneously through lactate producing processes (Hellsten & Bangsbo, 2007). In addition, Pate & Kriska (1984) can tell us that training increases the mitochondria's production of enzymes which betters the athletes requirements to transform nutrition to energy for the muscles to perform.

There is no doubt that endurance is critical for a football player to perform, but strength and speed is also very important (Gjerset et al., 2015). And as Hoff & Helgerud (2004) says, maximal strength training will better the work economy so the player can save more energy at the given intensity. This will help the player maintain a higher amount of high intensity runs and sprints later in the match, which according to Datson et al. (2014) is a very important factor for a team´s performance. Their study on female football players found that elite athletes covered 28% more distance in high intensity running and 24% more distance sprinting than players at a moderate level. They also observed a drop in high intensity running distance both within and between the two halves. Other studies have also found development of fatigue during football matches, which implies the lack of ability to maintain performance at higher intensity over time (Krustrup, Mohr, Ellingsgaard & Bangsbo, 2005). Fatigue will also result in lack of ball control, passing and lower intensity in general. These factors can at worst decide the match´ end result due to the fact that most goals is scored at the very end of a football match (Leite, 2017), as the players shows more signs of exhaustion at this time (Krustrup et al., 2005).

Maximal strength in lower extremities is related to running economy, studies have shown (Heggelund, Fimland, Helgerud & Hoff, 2013; Støren, Helgerud, Støa & Hoff, 2008). It is also found that heavy strength training contributes to reduced oxygen consume, heart rate, blood lactate and rate of perceived exertion, or "RPE" (Rønnestad, Hansen & Raastad, 2011). Physiological and biomechanical factors can also influence the athlete´s running economy. For instance, strength training can increase the muscles elasticity, where immediate eccentric energy will increase the concentric energy of a movement (Pate & Kriska, 1984). In addition, Henneman´s size principle explains how the need of power and activation of motor neurons is proportional, and the required load determines the degree of recruitment (Henneman, 1985). Therefore, a stronger muscle could delay recruitment of unnecessary motor neurons and apply these as needed.

Body composition describes what the body is made of, and includes proteins, minerals, fat, and water. This is used to give precise information regarding a person's health and weight status and is commonly used in professions concerning nutrition, medicine, physiology and sports science (Thibault, Genton & Pichard, 2012). In this study we are focusing on the whole body, or "anthropometry", which refers to the measurement of the human individual (Jackson & Pollock, 1985).

There are multiple methods to measure body composition. Field methods is often used because they are easy to use, do not require much time, they are noninvasive and nonexpensive. Examples are skinfold caliper measurements, bioelectrical impedance analysis (BIA), and body mass index (BMI). These methods are not as precise as the ones that require heavier equipment in a lab, like computed tomography (CT), magnetic resonance imaging (MRI), and the one used in this study; Dual energy X-ray absorptiometry (DXA).

Studies has shown that football players are quite the homogeneous group when it comes to anthropometry and body composition (Calbet et al., 2001; Milanese et al., 2015; Radzimiński et al., 2020; Silvestre et al., 2006; Sutton et al., 2009). Their studies have shown that male football players´ body fat varies between 6-20%, and 6-10% in England's highest division. They have also observed that elite football players have higher values in bone mineral density, lean body mass and a lower BF%. The average height of professional football players was found at approximately 180-181 cm. However, studies can´t really confirm whether height or weight is an advantage or not. Sutton et al. (2009) found some between-position

differences where the goalkeepers was significantly heavier than midfielders and attackers. Beyond that, it is hard to say what is better.

Studies investigating position-specifics in football has been more vital over the last years. This can help the coaches with more specific feedback for their players and detailed training planning to specify their trainings towards a more realistic match situation (Baptista, Johansen, Figueiredo, Rebelo & Pettersen, 2020). Professional football clubs is using this for every single match and training session for evaluation, to maximize their potential and of course to prevent injuries or health issues (Williams, 2013).

It has been found that lean body mass and body fat percentage is related to sprinting and jumping performance in male football players (Radzimiński et al., 2020; Silvestre et al., 2006). It is also found correlation between sprinting, jumping and aerobic capacity, and a high LMM with a low BF%. Low BF% is also proven to associate with aerobic and anaerobic capacity (Alemdaroğlu, 2012). In addition, fat percentage has no direct importance in muscle work and it is said that the storage component of body fat is a deadweight factor, meaning the athlete has to carry weight in situations like jumping, running and change of directions due to gravity (Sutton et al., 2009).

In general, studies have shown that top-level football players cover more total distance and high intensity running matched to lower level players (Bangsbo, Nørregaard & Thorsø, 1991; Mohr, Krustrup & Bangsbo, 2003). We have also seen that elite players have a lower BF% than players at a moderate level (Sutton et al., 2009). However, body composition and physique among footballers seem to vary a lot (Nikolaidis & Vassilios Karydis, 2011). We also find some world class players with an atypical physique, making this issue even more interesting to observe. Thus, there are rather few studies investigating the relationship between body composition and physical match performance directly (Radzimiński et al., 2020). I want to study this theme to increase understanding regarding this subject, and maybe fill a gap in the literature.

It is safe to say that football is a complex sport with its physical, technical, tactical, biomechanical, and phycological factors demanded to achieve performance of quality. The scientific work in this study is based on highly trained male football players from the highest division in Norway to observe the relationship between body composition and physical match performance during their home games throughout the 2021 season. As mentioned, there are

many crucial skills and characteristics needed to rule the game of football. In this study, dual energy X-ray absorptiometry (DXA) was used to collect information regarding the players´ body fat percentage [BF%] and lean muscle mass [LMM], while ZXY Sport Tracking system was used to collect match physical performance as total distance [TD], high intensity running [HIR], sprint distance [SpD], max speed and acceleration [ACC].

The hypothesis is that (a) BF% will have a negative association with total distance, and (b) a positive relationship will be observed between lean muscle mass and HIR and max speed variables.

3 Methods

The strategy of research for this scientific work is based on collecting and analyzing quantitative data. This research strategy is used to develop representative synopsis on general relations, and to test hypothesis´ and theories. It´s a process that includes quantification and data analysis and has a deductive methodology. The data is analyzed with the help of statistics and presented as numbers, providing unbiased results for generalization to a larger population (Ringdal, 2013). A quantitative approach is mostly based on a theory built by previous research, and a researcher´s own experiences in the area. After structuring and shaping theories into testable hypothesis or defined purposes, the empirical data collection can begin. Then it´s time for statistical analysis, were the collected data is considered up against previous literature to be confirmed or denied (Olsson, Sörensen & Bureid, 2003).

3.1 Study design and participants

This is a quantitative observational study where I have observed the effect of body composition on match physical performance in highly trained male football players. This design is used to gather quantitative data from a sample for statistical description of a whole population, often used to describe occurrence, or to examine relationships (Ringdal, 2013).

A male football team competing in the highest division in Norway participated in this study. Based on the criteria proposed by McKay et al. (2022), the players within this team was classified as highly trained since a) all players had a maximal to near maximal training volume for their sport, and b) was competing at a national, but not international level. The study was approved by the Norwegian Centre for Research Data (NSD) with reference number: 192295. Both coaches and players all received a thorough review of the experimental measures and potential discomforts associated with the study before giving their written informed consent to participate.

3.2 Data collection

Monthly body composition measurements via DXA were carried out on each player throughout a five-month period starting early 2021. In addition, every home match during the same period was tracked with the ZXY Sport Tracking system.

All data collection was done at the test lab and the football field belonging the teams home stadium. All players were familiar with the ZXY equipment, so no further education had to be done. DXA was for most players a brand-new experience, but as straight forward as it for the subject, just a quick review was enough pre scanning.

Goalkeepers were not tracked, and positions were recorded as defender, midfielder, or forward. All players needed at least one match start and one DXA scan within the same month for their data to be included. Matches in which a player was substituted on were not included. Also, because of the match-to-match variability in physical performance, a five-month time perspective was taken to ensure that the sample constituted a high number of matches. A total of six matches were recorded, two against top half finishers, two against mid-table teams, and two against teams in the bottom half. The opposition level of the teams was based on their final league position. The five-month time perspective also ensured that the player´s physiological and anatomical starting point remained somewhat unchanged during the test period. The final sample therefor consisted of 15 players with an age/weight/height of 24.8/77.4/181.7.

3.3 Protocols and equipment

3.3.1 Dual Energy X-ray Absorptiometry (DXA)

At the test lab associated with the team´s home stadium there´s an "GE Lunar Prodigy" DXA device. With characteristics as high precision and the lowest radiation dose on the market, it is the most popular DXA system worldwide. The X-ray measurement in such a body analysis applies four units of radiation, which is measured in micro sievert (μSv), and constitutes a very low health risk. In comparison, we receive twice as high a radiation dose daily through different sources, a flight across the Pacific Ocean gives ten times the radiation and a mammography give a 100 times higher radiation dose. In addition to high accuracy and low radiation dose, DXA is fast, reproducible, and somewhat inexpensive (Bazzocchi et al., 2014).

The gold standard for body composition is cadaver analysis, so no in vivo technique may be considered to meet the highest criteria of accuracy (Wells & Fewtrell, 2006). However, the latest generation densitometer of our manufacturer (GE Lunar) is improved from earlier and is also compared as a gold standard DXA device in assessing body composition in humans (Bazzocchi, Ponti, Albisinni, Battista & Guglielmi, 2016). In addition, the validity and

reliability of DXA is generally approved by a string of validation studies comparing DXA to cadaver analysis (Chen, Wilson, Khaksari, Cowley & Enriori, 2012; Suster et al., 2003).

Body hydration as well as stomach intestinal content may influence body composition. It appears that lean body mass increases because of meals (Nana, Slater, Hopkins & Burke, 2012). There is also shown decreased total mass and lean muscle mass (LMM) during intense activity due to dehydration. In addition, fluid re-compartmentalization during exercise is forcing blood volume from the torso to the periphery affecting increased lean mass an total mass of limbs and at the same time decreased lean mass and total mass of torso ((Nana et al., 2012). A strict test protocol was therefore required. The subjects were told to eat as usual the day prior to scanning. They were overnight-fasted and came in for DXA measurements early morning pre-breakfast and training session to ensure little to no variation in stomach and intestinal content. For 6-7 minutes, the subjects had to lay very still on the DXA bed, wearing nothing but their underwear. This standardized protocol is in accordance with other studies on the very same test (Garthe, Raastad, Refsnes, Koivisto & Sundgot-Borgen, 2011). In addition, monthly measurements with the very same strict protocol reduces the coefficient of variation, which is found to show as much as 3% variation in BF in the very same DXA device (Garthe et al., 2011).

3.3.2 ZXY Sport Tracking System

Different technologies are used for tracking of players´ match activity. Most commonly are semi-automatic systems based on multiple cameras, GPS systems based on satellite signals and local position measurement (LPM) systems based on radio signals. The LPM system, which is used in this study has proven to be more precise than the GPS systems, providing data with approximately 10 cm deviation from actual distances during football matches (Svein Arne Pettersen & Brenn, 2019; Svein A Pettersen, Johansen, Baptista, Halvorsen & Johansen, 2018).

The stadium was equipped with a stationary radio-based tracking system (ZXY Sport Tracking System, Trondheim Norway) which was used to carry out players match activity profiles. Based on the 2.45 GHZ ISM band used for radio communication and signal transmissions, the ZXY system is tracking all the players´ movements and activities during the whole football match. It collects information regarding their max speed, high intensity

running, total distance, acceleration, sprinting etc. with high precision. Max speed was defined as the absolute highest speed reached during the match. High intensity running was defined as speed > 19.8 km/h and sprint as speed > 25.2 km/h. Acceleration was defined as a positive pace alteration exceeding 2 meter per second during > 0.5 seconds. These speed thresholds applied for each locomotor categories were chosen based on previous literature (Baptista, Johansen, Seabra & Pettersen, 2018; Bradley et al., 2009; Dalen, Jørgen, Gertjan, Geir Havard & Ulrik, 2016). Each player wore a specially designed belt, wrapped tightly around the waist, with an electronic sensor system at the players lumbar spine. Mounted in light poles and in the tribune roof around the pitch, 10 stationary sensors compute the positional data from the players belts by running advanced vector-based processing of the received radio signals. These sensors works with overlapped zones to eliminate factors like obstruction and blocked signals, ensuring redundancy and reliability (Bendiksen et al., 2013).

The matches were all played on artificial grass surface during the 2021 season.

3.3.3 Statistical analysis

Statistical analysis was done using IBM SPSS v.28.0 (SPSS, Chicago, USA) and all results are expressed as mean $\pm$ 95% confidence intervals unless otherwise stated.

Multiple linear regression is often used to estimate the association between a dependent variable (for example TD) and two or more independent variables (for example BF% and position) when the dependent variable is measured at the ratio level. However, this method may bias the results when the assumption of independence is violated such as in this case where there are repeated measures of matches, and uneven number of measurements per player and per position. To deal with this I used linear-mixed modeling to control for the variation due to the random factors above. In addition, to adjust for substitutions and different match lengths, all physical performance variables, except for max speed, were divided by playing time. Also, since most variables encompassed different units (e.g., max speed in m/s per minute, body fat as a percentage, total distance in meters per minute), all variables were rescaled with mean of 0 and a standard deviation of 1. In SPSS, each model was therefore made with the given rescaled match-derived physical performance (either total distance/minute, high-speed running distance/minute, etc.) as the dependent variable, and the given rescaled body composition variables (BF% and LMM) as the independent variables. In

addition, since match physical performance is strongly associated with playing position, position was entered as an independent variable as well, with midfielder and forward coded as dummy variables. Finally, to deal with the violation of the assumption of independence; match id (match_slug_name) and player id (name) were entered as random factors.

3.4 Reliability

This chapter will explain the reliability of the results in this study.

By using dual energy X-ray absorptiometry (DXA) for measuring the players´ body composition I feel confident that I have retrieved high quality data. The DXA device I´ve used is considered the gold standard for body composition measurements when it comes to sports science, and multiple validation studies has accepted its accuracy and reliability (Bazzocchi et al., 2016; Chen et al., 2012; Suster et al., 2003).

ZXY was used to track the players´ every single movement during the matches. This is a local position measurement (LPM) systems based on radio signals, and has proven to be more precise than systems based on GPS (Svein A Pettersen et al., 2018). Stevens et al. (2014) found the ACC-measurements acceptable, but some limitations regarding the accuracy of max speed measurements. However, a practical validation have proven the ZXY Sport Tracking System valid, and the credibility of in-match max speed needs no criticism, a newer study shows (Ryslett, 2019).

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