UiT The Arctic University of Norway

School of Sports Sciences, Faculty of Health Sciences

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

Article

Thomas Endresen

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Abstract

The aim of this study was to estimate the effect of body composition on match physical performance in highly trained male football players. For this purpose, body composition and match physical performance were collected over a five-month period from a Norwegian men´s team playing in the top division during the 2021 season. 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]. 15 players with mean (standard deviation) age, weight, and height of 24.8 (2.9) years, 77.4 (8.0) kg, and 181.7 (7.2) cm, constituted the sample. Due to missing observations, analysis was done both for complete and imputed cases, with the full dataset containing 62 observations. Linear-mixed modeling was used to estimate the effect of LMM and BF%, adjusted for playing position, on match physical performance. The largest associations were found between BF% and TD and between LMM and max speed, respectively. A one standard deviation increase in BF% decreased the relative total distance covered during match-play by ~0.3 standard deviations, while a one standard deviation increase in LMM increased max speed by ~0.3 standard deviations. However, the confidence intervals for all examined associations were wide, and no significant findings were found. Based on the results from this study, the effect of body composition on match physical performance is likely trivial compared to playing position.

1 Introduction

With billions of supporters, more than 240 million active players and professionally played in almost every nation, football is the world's most popular sport (Andersen et al., 2016; Reilly & Williams, 2003). During a football match the players perform a wide range of physical skills including running, jumping, sprinting, tackling and more. Besides these physical skills, both psychological, tactical, and technical skills are needed for a team to achieve superior performance (Dolci et al., 2018). Although not often mentioned, the body composition of the players may also play a role. For example, in many other sports, the body composition of the athlete is highly related to competitive performance (Högström, Pietilä, Nordström & Nordström, 2012; Stöggl, Enqvist, Müller & Holmberg, 2010; Ugarkovic & Kukolj, 2002).

Previous studies to date have focused on the association between body composition variables and physical performance tests. For example, it has been found that lean muscle mass (LMM) and body fat percentage (BF%) is related to 10 and 40 yard sprints in male football players (Radzimiński, Szwarc, Padrón-Cabo & Jastrzębski, 2020; Silvestre, West, Maresh & Kraemer, 2006). In addition, previous literature (Barbieri et al., 2017; Nikolaidis et al., 2015) also indicates correlation between sprinting and aerobic capacity, and a high LMM with a low BF%. Low body fat percentage is also positively associated with performance in the Wingate anaerobic power test and 10-30 meter sprints (Alemdaroğlu, 2012). Physiologically, 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 this weight in situations like jumping, running and change of directions due to gravity (Sutton, Scott, Wallace & Reilly, 2009).

Maximal strength has previously shown a large correlation ($r = 0.6$) with lean muscle mass (Pinto, 2012), and maximal strength in lower extremities is related to running economy (Heggelund, Fimland, Helgerud & Hoff, 2013; Støren, Helgerud, Støa & Hoff, 2008). There is also registered that heavy strength training contributes to reduced oxygen consume, heart rate, blood lactate and rate of perceived exertion, or "RPE" (Rønnestad, Hansen & Raastad, 2011). Hence that maximal or heavy strength relates to aerobic and anaerobic performance, which is important to a lot of high intensity actions during a football match (Hellsten & Bangsbo, 2007), it is tempting to think that there is a relationship between body composition and performance as well.

Studies on physical performance in football has shown that football players on elite level cover more distance in high intensity running and sprinting than players at a lower level (Mohr, Krustrup, Andersson, Kirkendal & Bangsbo, 2008). Coutts et al. (2010) registered that the mean ($\pm$ SD) total distance and high intensity running distance for an elite-level Australian team were 12,939 $\pm$ 1145 m and 3880 $\pm$ 663 m respectively. These large variations among the players are probably somewhat affected by playing position and situational factors of the match. When Baptista, Johansen, Seabra and Pettersen (2018) investigated position specific physical performance in elite women´s football, significant differences between certain positions were found. However, there is also found some between-position differences in football players when it comes to anthropometry (Sutton et al., 2009), making the matter of body composition in football an interesting issue to explore.

Yet, among footballers we find that body composition and physique vary a lot (Nikolaidis & Vassilios Karydis, 2011). Differences and changes in body composition can give information regarding changes in nutritional status or the adaptation to different types of training (Andreoli et al., 2003). Some even stand out due to their atypical body composition and is still stated as world class players against all odds. Mostly, measuring body composition is about generalization of typical characteristics in athletes. Thus, there are rather few studies investigating the relationship between body composition and physical match performance directly (Radzimiński et al., 2020). While body composition has shown to differ between players of higher and lower level (Masanovic, Milosevic & Bjelica, 2019), no study to date has investigated the association between body composition and match physical performance between players of the same level.

The aim of this study was therefore to examine the effect of body composition on match physical performance in highly trained male football players. Based on the literature, I hypothesize that (a) BF% will have a negative association with total distance, and (b) a positive relationship will be observed between lean muscle mass and SpD and max speed variables.

2 Methods

2.1 Study design and participants

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 received a thorough review of the experimental measures and potential discomforts associated with the study before giving their written informed consent to participate.

2.2 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.

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 final sample therefore consisted of 15 players with an age/weight/height of 24.8/77.4/181.7.

2.3 Protocols and equipment

2.3.1 Dual Energy X-Ray Absorptiometry (DXA)

At the test lab associated with 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 analysis 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).

Body hydration as well as stomach and 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 mass 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 and 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 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.

2.3.2 ZXY Sport Tracking System.

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 collected physical variables such as high intensity running, total distance, acceleration, sprints, max speed etc. with high precision. High intensity running was defined as speed $\geq$ 19.8 km/h and sprint as speed $\geq$ 25.2 km/h. Acceleration was defined as a positive pace alteration exceeding 2 meter per second during $\geq$ 0.5 seconds. These speed thresholds applied for each locomotor categories were chosen based on previous literature (Baptista et al., 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.

2.4 Missing data

All data were inspected for improbable values, and, if deemed improbable, set as missing. Two were found in the DXA data for BF%, owning a wrong data entry. For ZXY, a max speed value was deemed improbable if above 10 m/s speed, while values for TD, HIR, SpD, and ACC were deemed improbable if 0. Also, if a player with a recorded playing time > 70 minutes had a recorded TD under 7000 meters, then TD, HIR, Spd, ACC, and max speed, were deemed improbable. Table 1 shows the percentage of missing values in the data.
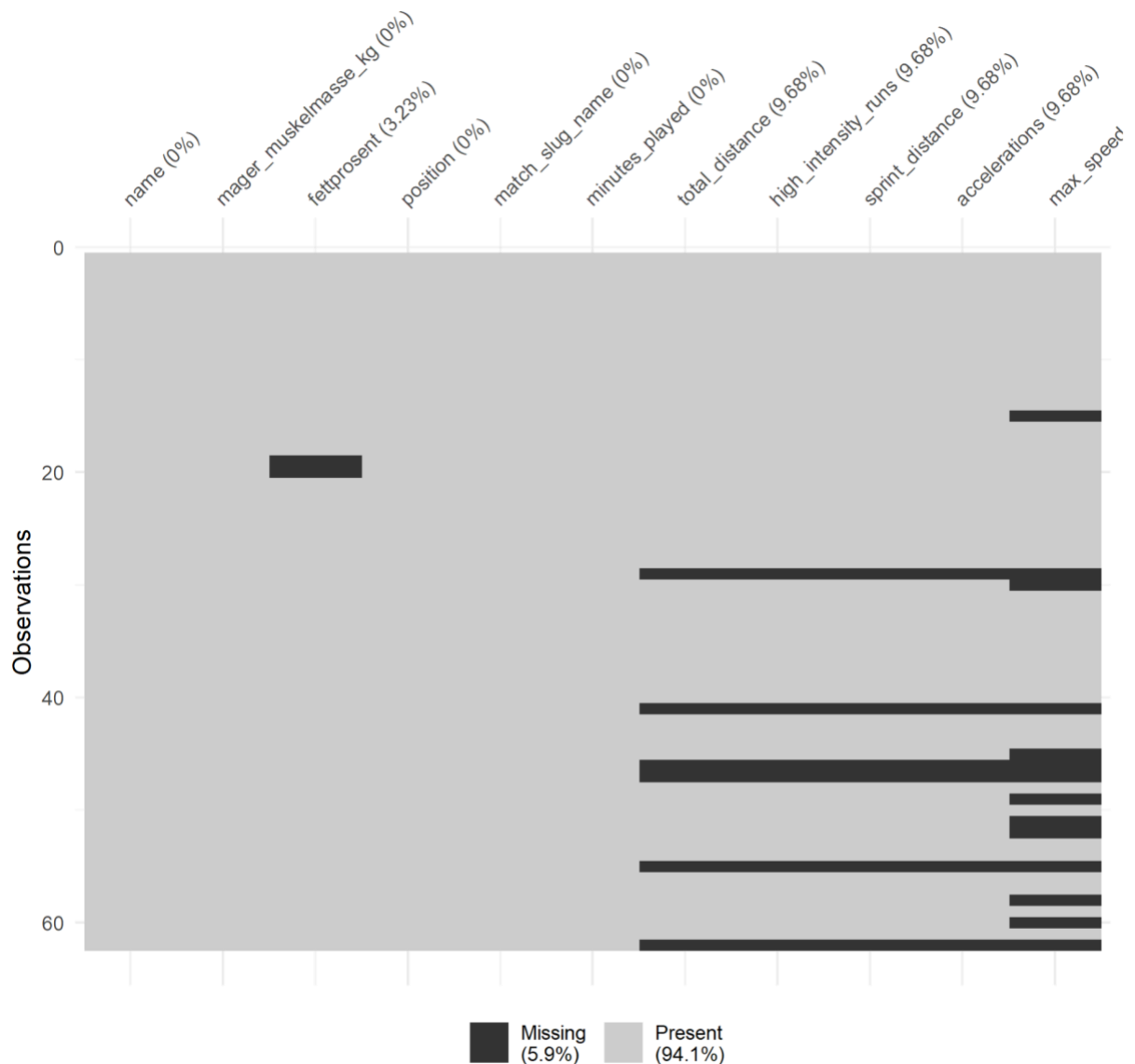
Figure 1: Overview of missing data.

As recommended by Borg et al. (2021), missing data should be imputed, and results reported for both non-imputed and imputed data. For the imputation itself, linear regression was chosen for the imputation of missing data for both BF% and match physical performance. BF% were imputed using a model with player name as the independent variables, essentially using the mean BF% of the player in question to impute the data. All physical performance variables were imputed using minutes played and position as the independent variables. The final imputed dataset contained 62 observations.

2.5 Statistical analysis

Statistical analysis was done using IBM SPSS v.28.0 (SPSS, Chicago, USA) while figures were made in R. All results are from the imputed dataset and expressed as mean + 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 Results

3.1 Descriptive statistics

A descriptive summary of the non-imputed and imputed datasets is given in table 1 and table 2.

Table 1: Descriptive summary of non-imputed dataset.

	LMM (kg)	BF (%)	TD (m/min)	HIR (m/min)	SpD (m/min)	ACC (n/min)	Max speed (m/s)
Defenders (n = 6)	69.6 ± 2.8	12.6 ± 2.6	124.7 ± 6.4	6.3 ± 2.1	0.9 ± 0.8	0.7 ± 0.1	8.0 ± 0.5
Midfielders (n = 8)	60.9 ± 4.3	11.6 ± 1.2	128.2 ± 8.3	8.6 ± 1.7	1.5 ± 0.7	0.8 ± 0.1	8.5 ± 0.5
Forward (n = 4)	62.7 ± 11	11.7 ± 2.5	126.8 ± 4.6	10.2 ± 2.3	2.0 ± 0.9	1.0 ± 0.1	8.5 ± 0.6

Table 2: Descriptive summary of imputed dataset.

	LMM (kg)	BF (%)	TD (m/min)	HIR (m/min)	SpD (m/min)	ACC (n/min)	Max speed (m/s)
Defender (n = 6; obs = 22)	69.6 ± 2.8	12.4 ± 2.5	124.8 ± 5.8	6.3 ± 1.9	0.9 ± 0.7	0.7 ± 0.1	8.0 ± 0.4
Midfielder (n = 8; obs = 28)	60.9 ± 4.3	11.6 ± 1.2	128.2 ± 8.0	8.6 ± 1.7	1.5 ± 0.6	0.8 ± 0.1	8.5 ± 0.4
Forward (n = 4; obs = 12)	62.7 ± 11	11.7 ± 2.5	126.8 ± 4.6	10.2 ± 2.3	2.0 ± 0.9	1.0 ± 0.1	8.5 ± 0.6

3.2 Effect of body composition on match physical performance

Figure 2 shows a forest plot of the standardized β coefficients + 95% confidence intervals for each model using the imputed dataset. The standardized β coefficients for the LMM and BF% describe the standard deviation change in physical performance for a one standard deviation change in the respective independent variable, controlled for the other variables in the model (position, and the other body composition variable). For playing position, the standardized β describe the change in physical performance when increasing the position from 0 to 1, controlling for other variables. Since defender was coded as 0, the standard deviation change in position is therefore relative to the defender. As shown, for body composition, the highest association was between max speed and LMM (β = 0.2 [-0.2, 0.6], p = 0.17), and TD and BF% (β = -0.3 [-0.6, 0.0], p = 0.07). However, neither were significant. The only notable difference between the imputed and non-imputed datasets was that the position-adjusted effect of BF% on TD was significant in the non-imputed dataset (β = -0.4 [-0.7, -0.1], p = 0.006). Position has a significant impact on physical performance, with forwards reaching higher max speeds and number of accelerations while covering greater HIR and Sprint distances compared to defenders. Midfielders also reached greater speeds compared to defenders.
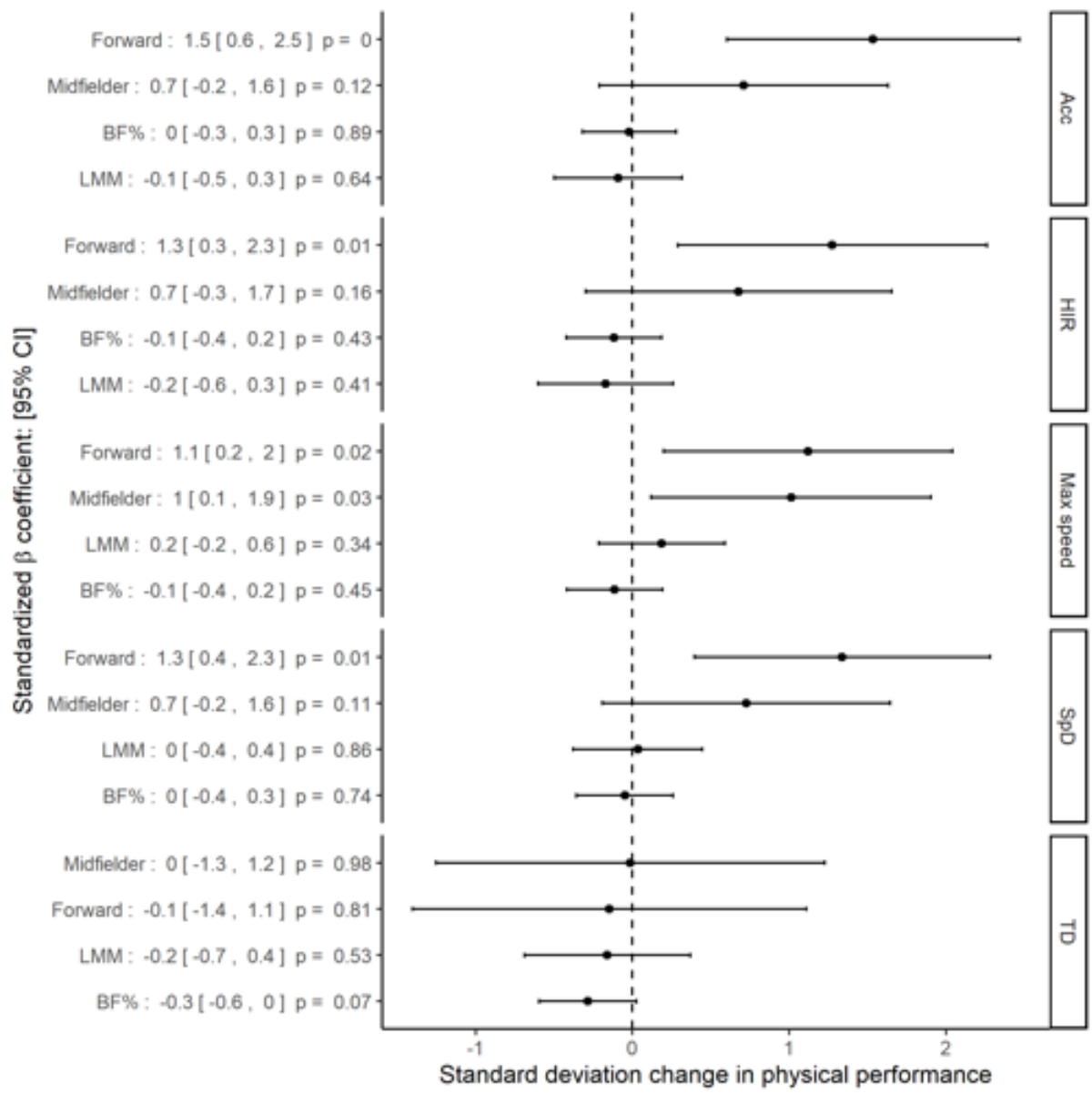
Figure 2. Standardized beta coefficients + 95% confidence interval for each model, arranged from positive to negative.

4 Discussion

This observational study is one of the first to study the effect of body composition on match performance in highly trained male football players. The hypothesis was that (a) BF% will have a negative association with physical match performance in football, and (b) a relationship will be observed between muscle mass and SpD and max speed variables.

The main finding of this study is that when controlling for playing position, body composition shows no significant relation to match performance in football. It´s not a lot to compare the findings in this study with, but it´s safe to say that football players are quite the homogenous group when it comes to anthropometrics and body composition (Calbet, Dorado, Díaz-Herrera & Rodríguez-Rodríguez, 2001; Milanese, Cavedon, Corradini, De Vita & Zancanaro, 2015; Radzimiński et al., 2020; Silvestre et al., 2006; Sutton et al., 2009). The players´ mean BF% and height in this study was 12.5% and 181.7 cm, quite the same as the average professional football player.

In this study, the largest positive association was found between max speed and LMM (β = 0.2). This could imply that having more lean muscle mass, especially in the lower body, could have an impact on max speed in the game. Physiologically, Henneman´s size principle show that the need of power and activation of motor neurons is proportional, and that the required load determines the degree of recruitment (Henneman, 1985). This explains how a bigger muscles ability to recruit motor neurons compared to a smaller muscle. It is well documented that running pace is affected by the dominant type of muscle fiber, running technic, age, neural conditions, the muscles´ length and girth, and elasticity (Pate & Kriska, 1984; Silvestre et al., 2006). However, though this association was positive, the confidence intervals was quite wide, meaning this association can have a wide range of compatible values, both more positive and more negative [-0.2, 0.6]. Also, the association in this study is small compared to playing position, telling us that playing position is a much more important factor affecting in-game max speed.

I also found that a higher BF% was negatively associated with total distance (β = -0.3 [-0.6, 0.0], p = 0.07, implying that an increase in BF% can decrease the distance covered in match, controlling for LMM, and playing position. Although the association was borderline non-significant (and significant with the non-imputed dataset), similar results are found elsewhere (Silvestre et al., 2006), and low BF% has also showed positive association with aerobic and

anaerobic capacity (Alemdaroğlu, 2012). Sutton et al. (2009), also describes fat as a deadweight factor, meaning the player is carrying that weight around with no direct importance in muscle work. This might make it easier to cover more distance with a lower BF%. In addition, excess body fat is said to correlate with fatigue, which is known to affect a player´s ball control, passing and their overall performance (Datson et al., 2014). However, professional football players´ body fat is usually quite low, and a percent or two might not affect them whatsoever.

It is shown that physical match performance of a football player is also affected by situational factor as scoreline, location and the opponent´s level (Lago, Casais, Dominguez & Sampaio, 2010). They found that the leading team´s players cover less high intensity distance versus when under. For every leading minute, a 1-meter decrease at maximal or sub maximal intensity was registered. By using data from matches against teams all over the league table I have somewhat controlled for the level, but I have not checked for match results to control for which team was superior in the specific matches.

I also found that playing-position greatly affects the physical demands during match-play, which several other studies show. For instance, Baptista et al. (2018) registered that center back players typically cover less total distance, HIR distance and sprinting distance than any other outfield position. Being big, fast, and strong is some of their most important characteristics in their job to stop attackers from scoring goals, and their demands is probably quite restricted due to the course of how the game is played. Studies show that defenders tend to be taller and heavier than midfielders and attackers, but they also have a lower BF% and a higher LBM% than most (Calbet et al., 2001; Milanese et al., 2015; Radzimiński et al., 2020; Silvestre et al., 2006; Sutton et al., 2009). In this study, I found a small association between BF% and total distance. Since the relationship between body composition and physical match performance is quite small compared to playing position, future studies should increase the sample size to have adequate and true relationship.

5 Limitations

The number of participants and observations in this study (n=15, obs=62) was too low to detect a significant relationship. However, the findings could be used as priors or to guide power calculations for future studies regarding the relationship between body composition

and physical match performance. A larger sample size could help in preventing type 2 errors. Also, the playing positions in this study were quite crude, and there could be difference within positional groups for example between central midfielders and wide midfielders.

I also did not check for interactions between playing position and body composition. For example, it could be possible that the physical demands for certain positions are modified by a higher or lower BF% or LMM. There is also the added complexity of football matches being affected by situational factors like the opponent, their own tactics, and the statistics during the game such as scoreline. These factors are quite hard to control for and are not controlled for in this study.

6 Conclusion

Controlled for playing position, the largest association was found between BF% and TD, and between LMM and max speed, respectively. However, the confidence intervals for all possible associations were wide, and no significant associations were found. Future studies should therefore increase the sample size accordingly. Compared to playing position, body composition likely has a small effect on match physical performance in highly trained male football players.

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