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Skinfold thickness in elite male professional football players: changes across 3 seasons including a COVID-19 lockdown period

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ABSTRACT

This study investigates variations in skinfold thickness in a European professional football team within and across multiple seasons, including before and after COVID-19 restrictions. Skinfold thickness was measured in 49 male players on 32 occasions across three seasons (2018/19, 2019/20 and 2020/21). Intra- and inter-seasonal trends were examined by comparing values for the sum of eight skinfolds (sum8) at key time points using linear mixed models. In each season, the largest differences in sum8 occurred after the preseason period. These differences ranged from a mean difference (M_{diff}) of −11.0 mm ($p < 0.001$) in 2018/19 to −4.8 mm ($p < 0.001$) in 2020/21. Increases in sum8 occurred after each off-season; however, the increase after the off-season before the 2020/21 season (which included the COVID-19 lockdown period) was the lowest in magnitude and was not statistically significant ($M_{diff} = 2.9$ mm, $p = 0.06$). Changes occurring in sum8 between the start and end of the competitive season did not follow a consistent pattern and were generally smaller in magnitude than the changes between other seasonal time points. Despite the notable heterogeneity in sum8 between players, changes within players generally followed a similar pattern between the different seasonal timepoints. In summary, changes in skinfold thickness were predominantly related to off-season and 'preparation for competition' periods. Increases in skinfold thickness can be mitigated during extended remote training periods with appropriate training and nutritional strategies.

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Body composition; seasonal trends; soccer

Introduction

In elite football, there are numerous factors which can impact a player's match day performance. There are elements that players can influence directly, such as body composition, which can be controlled through effective dietary and training strategies. A footballer's body composition is generally considered an important determinant of performance. As such, it has been suggested that an objective of the professional football player should be to maintain a body composition throughout the season that is optimal from both a health and performance perspective (Suarez-Arrones et al. 2018).

However, 'optimal' values of body composition for 'football performance' remain unclear. This is due to the difficulty in measuring performance and evaluating the factors that may contribute to successful outcomes, as well as the variability in player physical characteristics. Therefore, there may be no single optimal value of body composition for a football player (Collins et al. 2021). Nonetheless, a player's performance is likely hindered by excess body fat, as it is may negatively affect a player's power-to-weight ratio (Gil et al. 2005; Masanovic et al. 2019) in activities which require the transfer of body mass both vertically (jumping) and horizontally (running) and impact mechanical stress that may increase the risk of injury (Suarez-Arrones et al. 2018). In contrast, sustaining very low values of body fat (lower than 30 mm) may compromise immune function, increase the risk of relative energy deficiency in sport (RED-S) and susceptibility to injuries, and ultimately health and performance (Moreira et al. 2014; Mountjoy et al. 2018).

The aim of this study was to investigate changes in skinfold thickness in elite level professional footballers within and across multiple seasons. It was hypothesised that skinfold thickness would significantly change over the course of a competitive season and across consecutive seasons and that a sustained break from normal training, including 91 days of home confinement imposed by COVID-19 quarantine period would lead to significant increases in skinfold thickness.

Materials and methods

Study design

To examine intra- and inter-seasonal changes in body composition amongst an elite European professional football team, a retrospective longitudinal analysis of body composition data

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Table 1. Schedule of skinfold thickness measurement across the study time period and corresponding table for presentation of results.

Seasonal time point	Month of measurement	Chart label
Start of preseason 2018/19	June 2018	Pre 18/19
End of preseason 2018/19	July 2018	Start 18/19
End of season 2018/19	May 2019	End 18/19
Start of preseason 2019/20	June 2019	Pre 19/20
End of preseason 2019/20	July 2019	Start 19/20
End of season 2019/20 (before COVID-19 lockdown)	February 2020	End 19/20
Start of preseason 2019/20 (after COVID-19 lockdown)	June 2020	Pre 20/21
End of preseason 2020/21	August 2020	Start 20/21
End of season 2020/21	April 2021	End 20/21
Start of preseason 2021/22	June 2021	Pre 21/22
End of preseason 2021/22	July 2021	Start 21/22

was performed. Data were collected on 32 occasions (approximately once every month) across the complete schedule for the seasons 2018/19, 2019/20 and 2020/21. Differences between skinfold thicknesses assessed at consecutive time points were examined statistically. For these comparisons, data from a total of 11 key seasonal time points were considered, including the start of preseason, end of preseason and end of season across the whole examined period (Table 1).

Participants

A total of 49 male players, 25 of whom were Internationals, from 15 different countries, participated in the study (mean (±SD) age 25.1 ± 4.8 years, body mass 80.7 ± 6.4 kg, height 182.9 ± 6.3 cm). Table 2 shows the distribution of players included in the study. The team typically competes in four competitions (Scottish Professional Football League, Scottish Cup, Scottish League Cup and U.E.F.A. Europa League). In seasons 2018/19, 2019/20 and 2020/21, the team participated in 60, 55 and 56 matches, respectively.

Players were evaluated over the course of three full competitive seasons (season 2018/19, 2019/20 and 2020/21) and the pre-season period of season 2021/22.

Informed consent

This assessment was part of their in-house performance measures; therefore, ethics committee clearance was not required (Winter and Maughan 2009). Informed consent for the collection of the data was obtained from all players that enabled the data collected to be used for research purposes. All data was anonymised.

Procedures

All players in the study underwent skinfold thickness assessments to correspond with the periodic, standard in-house monitoring of body composition. Skinfold thickness was measured by the same International Society for the Advancement of Kinanthropometry (ISAK) Level 1 anthropometrist following the protocol established by the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al. 2019). The method of assessment selected to perform the measurement of skinfold thickness at multiple sites was the ISAK 8-site measurement (triceps, biceps, subscapular, iliac crest, supraspinale, abdominal, anterior thigh and medial calf) (Ackland et al. 2012). All landmark sites were first identified, marked and measured before any measurements were recorded, with each site being measured in succession to avoid an experimenter basis and to reduce the effects of skinfold-compressibility prior to repeating measurements for a second time (Norton and Eston 2018). The mean of two measures was used for the analysis and a third measure was triggered if the technical error of the measurement was exceeded. In the case of three measurements being taken, the median measure was used. The intra-tester TEM ranged from 2.5% to 4.4% over the course of the study time period, which is below the 5% standard required for ISAK Level 1 accreditation (Perini et al. 2005).

To ensure standardisation of the test administration across the entire study period, testing was scheduled at the same time of day (between 0800 and 1100 h) with players presenting in a fasted state prior to performing any exercise. Harpenden skinfold callipers (Cranlea, Birmingham, UK) which are calibrated on an annual basis were used in the collection of the data.

Table 2. Number of individual players, by playing position, in each season and across the entire study time period.

	Season 2018/19	Season 2019/20	Season 202021	Entire study time period
Goalkeepers	4	4	2	5
Defenders	10	9	9	15
Midfielders	15	14	11	20
Strikers	4	3	5	7

Stature was measured with a stadiometer (SECA 711, Hamburg, Germany). Body mass was measured on a digital scale (SECA 876, Hamburg, Germany) each time body composition was assessed, to the nearest 0.1 kg, pre-training, as well as pre-breakfast, wearing minimal clothing.

Statistical analysis

Descriptive analysis

The pattern of change in the mean sum of eight skinfolds (sum8) at squad level over the study period was plotted in a line chart, with error bars representing minimum and maximum values. In addition, box plots are presented showing the minimum, maximum, mean, median, interquartile range, and individual player values, using all available sum8 measurements at key seasonal time points (Table 1), overall and by playing position.

Linear mixed model analysis

Linear mixed models were used to provide a robust framework to explore intra- and inter-seasonal changes in sum8 using the full set of data, while accounting for correlated and longitudinal measurements, individual heterogeneity, unbalanced data and the presence of missing data. We adopted a 2-stage process for the LMM. First, we explored the overall effect of seasonal time point across seasons by modelling absolute sum8 values with seasonal time point (start of preseason, end of preseason and end of season) and season (2018/19, 2019/20, 2020/21, 2021/22) as fixed effects and player and position as random effects (the 'absolute LMM'). The start of preseason and season 2018/19 were used as reference categories for the seasonal time point and season-fixed effects, respectively. Second, to further assess *changes* between consecutive seasonal time points, we used an LMM on paired time points with player and position as random effects (the 'paired LMM'). The paired LMM included players with data for consecutive time points only. In addition to testing differences between sum8 across key seasonal time points, the paired LMM analysis was repeated for body mass and each of the eight individual skinfold sites. Separate LMM analyses to explore the independent effect of the playing position on changes in sum8 were not performed due to the small sample size in some groups. Statistical significance was set at the conventional $p < 0.05$ threshold to ease the description of the results. All analyses were performed using IBM Statistics SPSS 27, GraphPad Prism 9.1.0, Python and Microsoft Excel.

Results

Descriptive analysis

Eleven of the 33 players had complete data in 2018/19, 19 of 30 in 2019/20 and 17 of 27 in 2020/21. Due to the changing nature of the squad only 10 players had complete data for each seasonal time point across the entire study time period. The highest mean sum8 between the end of season 2018/19 to the end of season 2020/21 occurred at the start of the time series, representing the only time point where the squad mean sum8 was above 60 mm (Figure 1). Mean sum8 at the end of pre-

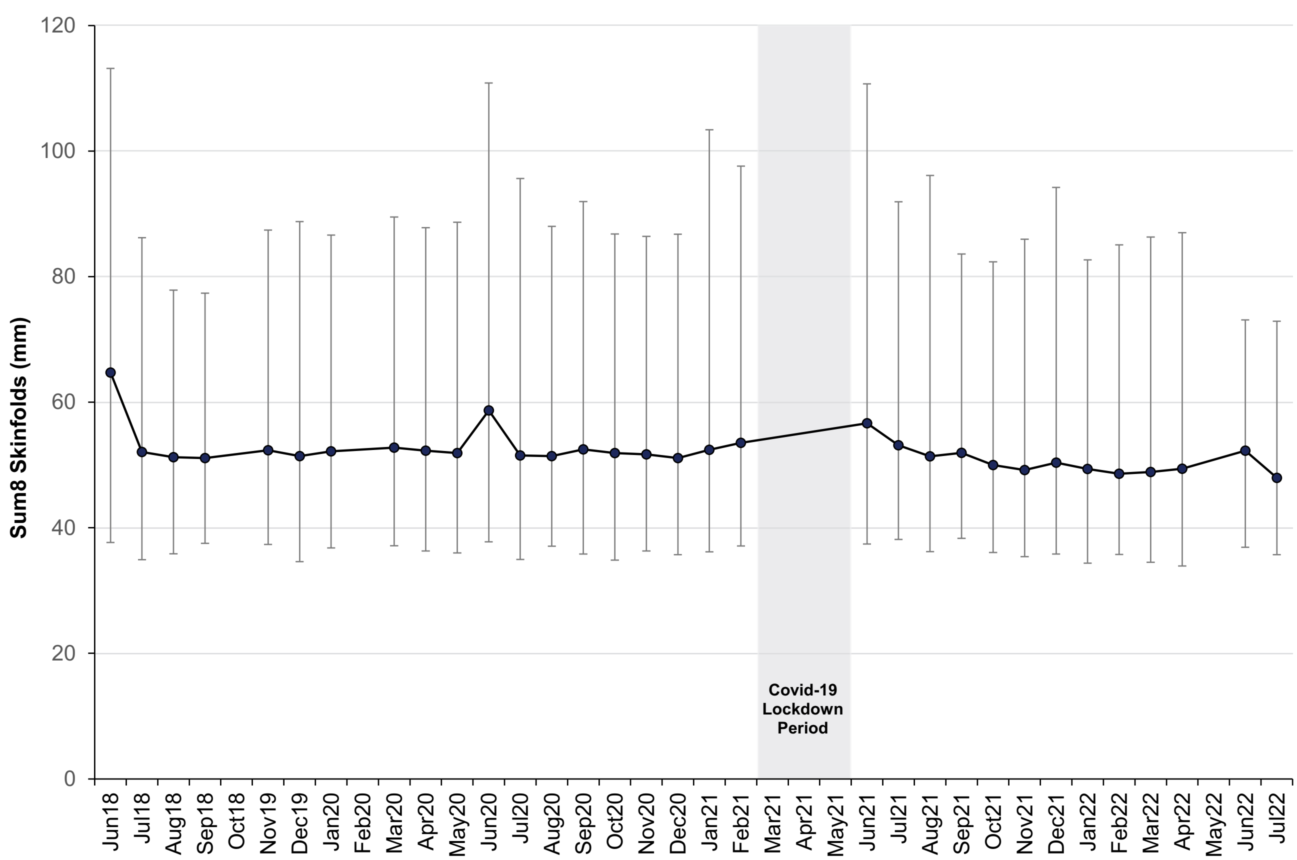

Figure 1. trend in mean squad sum8 across the study time period. Error bars show minimum and maximum.

season 2021/22 (July 2021) was the lowest observed over the entire time series. The error bars in Figure 1 demonstrate a wide variation in sum8 across the squad, ranging from values below 40 mm to above 80 mm at each measurement time point.

The box and whisker plots shown in Figure 2 provide a more detailed picture of the distribution of individual data at key seasonal time points. The peaks in mean squad sum8 observed at the start of preseason across each season in Figure 1 are driven by an increased dispersion of values across the squad, but particularly one or two players with values notably higher than the rest of the squad. Figure 3 compares mean (M) sum8 between positional roles across the entire study time period. Based on this descriptive analysis, goalkeepers ($M = 58.4$ mm, min = 47.6 mm, max = 61.6 mm) had the highest mean sum8 followed by strikers ($M = 52.3$ mm, min = 40.7, max = 89.6 mm). Defenders ($M = 44.4$ mm, min = 37.6, max = 74.6 mm) and midfielders were the positional roles with the lowest mean sum8 across all seasons ($M = 46.3$ mm, min = 39.8, max = 63.6 mm).

Statistical analysis

The absolute LMM shows that there were statistically significant increases in sum8 between the end of a season and the start of the following season, with significant decreases occurring during the pre-season (Table 3). The co-efficient for the fixed effects of season also indicates that the squad average sum8 decreased season on season after accounting for individual heterogeneity, with the lowest squad sum8 occurring in season 2021/22.

Table 4 presents the results from the paired LMM. The largest seasonal mean differences (M_{diff}) in sum8 occurred before and after preseason in 2018/19 ($M_{diff} = -11.0$ mm, 95% confidence interval −15.2 to −6.1 mm), $p < 0.001$), 2019/20 ($M_{diff} = -7.5$ mm (−10.2 to −4.7 mm), $p < 0.001$), 2020/21 ($M_{diff} = -4.8$ mm (−7.3 to −2.2 mm), $p = 0.002$) and 2021/22 ($M_{diff} = -5.8$ mm (−7.7 to −3.9 mm), $p < 0.001$) (Table 3). Increases in sum8 occurred in the closed season before the 2019/20 season ($M_{diff} = 4.9$ mm (1.3 to 8.4 mm, $p = 0.008$)) and the 2020/21 season, which coincides with the COVID-19 lockdown period, though the latter was not statistically significant ($M_{diff} = 2.9$ mm (−0.1 to 5.8,$p = 0.06$)). The largest increase in mean sum8 between two time periods occurred during the closed season before 2021/22 ($M_{diff} = 6.2$ mm (3.1 to 9.2 mm), $p < 0.001$). Changes in sum8 during the competitive season were mixed across the study time period, with no significant change in 2018/19 ($M_{diff} = -0.45$ mm (−2.9 to 2.0 mm, $p = 0.72$)), a significant increase in 2019/20 ($M_{diff} = 1.9$ mm (0.1 to 3.8 mm, $p = 0.04$)); and a significant decrease in 2020/21 ($M_{diff} = -2.5$ mm (−4.4 to −0.5 mm, $p = 0.02$).

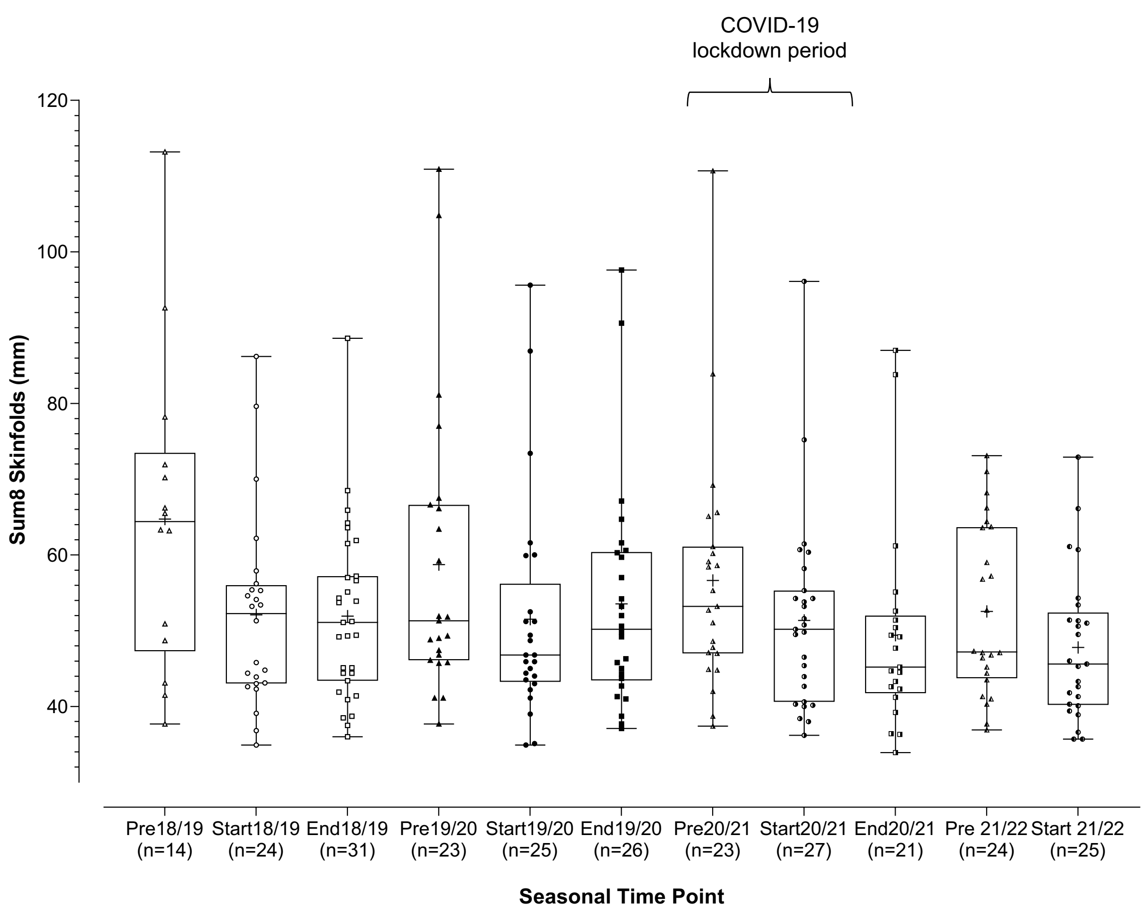

Figure 2. boxplot of sum8 values at key seasonal time points. The horizontal line represents median, the + sign represents the mean, the box represents interquartile range and the error bars provide minimum and maximum values. Individual player values are shown as filled shapes (triangles = pre-season; circles = start of season; squares = end of season).

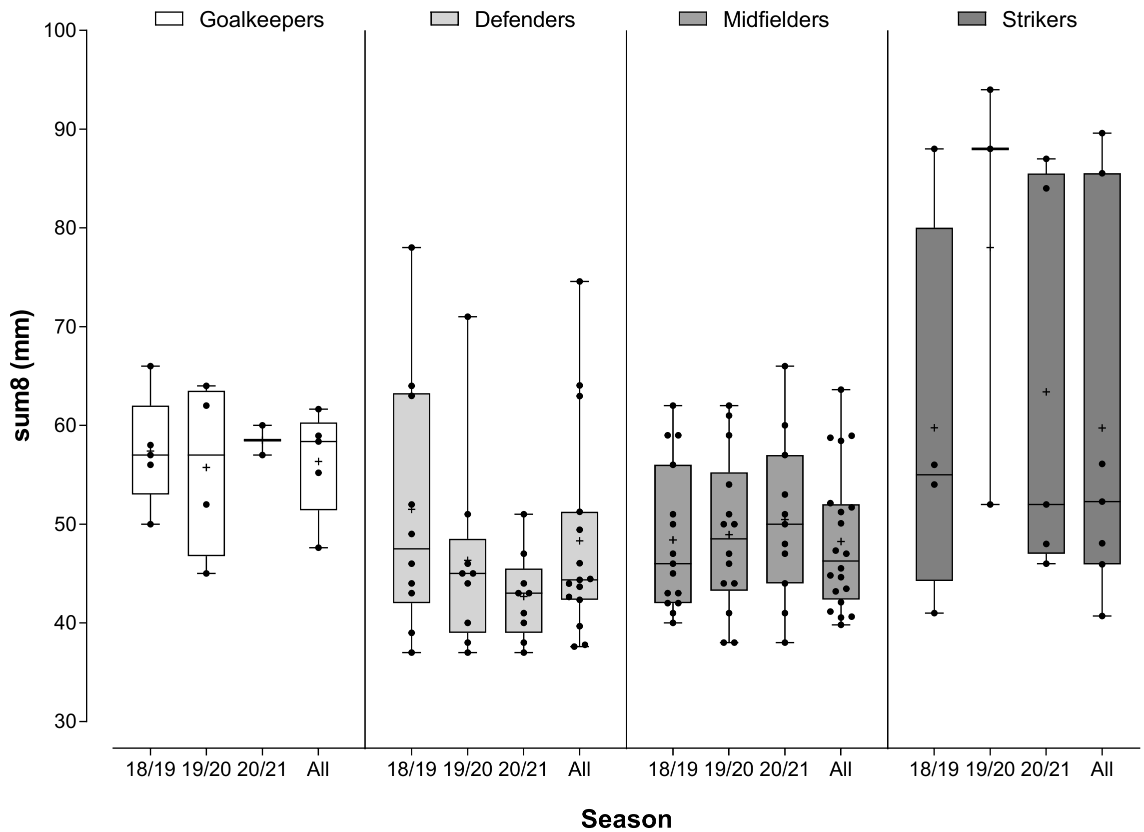

Figure 3. Boxplot of sum8 values in each positional role across 2018/19, 2019/20 and 2020/21 and across all seasons. The horizontal line represents median, the + sign represents the mean, the box represents interquartile range, and the error bars provide minimum and maximum values. Individual player values are shown as filled circles.

Table 3. Results from a linear mixed model of absolute sum8 with season and seasonal time point as fixed effects and player and position as random effects ('absolute LMM').

	Coefficient	95% confidence interval	*p* value
Intercept (Start of preseason 2018/19)	59.0	55.2 to 62.8	<0.001
Seasonal Time Point (End of preseason)	−6.9	−8.4 to −5.3	<0.001
Seasonal Time Point (End of season)	−7.2	−8.9 to −5.4	<0.001
Season (2019/20)	−2.3	−4.3 to −0.3	0.02
Season (2020/21)	−3.3	−5.4 to −1.2	0.002
Season (2021/22)	−4.6	−7.0 to −2.2	<0.001

Supplementary analysis

Results from analysing data for each skinfold site are presented in the Supplementary Appendix. In general, the seasonal changes for individual sites showed a similar pattern to sum8. The largest changes in squad mean skinfold thickness were observed during the off-season (when skinfold thickness increased) and during pre-season (when skinfold thickness decreased). During the competitive season, skinfold thickness typically decreased or remained similar to that observed at the end of pre-season. Body mass was broadly consistent across the study time period: the only statistically significant change was

Table 4. Results from a paired comparison of sum8 at key seasonal time points using linear mixed models with player and position as random effects ('paired LMM').

Paired comparison	n	Coefficient	95% confidence interval	*p* value
End of preseason 2018/19 vs Start of preseason 2018/19	14	−11.0	−15.2 to −6.1	<0.001
End of season 2018/19 vs End of preseason 2018/19	21	−0.5	−2.9 to 2.0	0.72
Start of preseason 2019/20 vs End of season 2018/19	18	4.9	1.3 to 8.4	0.01
End of preseason 2019/20 vs Start of preseason 2019/20	22	−7.5	−10.2 to −4.7	<0.001
End of season 2019/20 vs End of preseason 2019/20	23	1.9	0.1 to 3.8	0.04
Start of preseason 2020/21 vs End of season 2019/20	20	2.9	−0.1 to 5.8	0.06
End of preseason 2020/21 vs Start of preseason 2020/21	23	−4.8	−7.3 to −2.2	<0.001
End of season 2020/21 vs End of preseason 2020/21	21	−2.5	−4.4 to −0.5	0.01
Start of preseason 2021/22 vs End of season 2020/21	24	6.2	3.1 to 9.2	<0.001
End of preseason 2021/22 vs Start of preseason 2021/22	25	−5.8	−7.7 to −3.9	<0.001

a 0.4 kg (−0.2 to 2.8, $p = 0.02$) increase in the off-season before the 2021/22 season. However, the magnitude of the change was similar to that seen at other seasonal time points (Table S9, Supplementary Appendix).

Discussion

The purpose of this study was to investigate changes in skinfold thickness in elite professional footballers over a time period spanning multiple seasons. The study also aimed to better understand intra-seasonal patterns, including the impact of the COVID-19 pandemic, and positional variations in skinfold thickness. The largest changes in skinfold thickness values occurred in the off-season period between the end and start of each season. Each year, the pre-season period led to decreases in sum8 values that offset the increase observed during the off-season. There was no clear pattern in mean sum8 during the course of the competitive season when comparing across the three seasons. The COVID-19 lockdown period that occurred between February and June in season 2019/20, and which involved players completing a remote training programme, did not result in a statistically significant increase in mean sum8. These data illustrate that body composition is a relatively stable parameter during the competitive season, with any large changes predominantly confined to periods of re-training following off-season breaks. This would suggest that despite large inter-individual variation, changes in body composition are related to a 'preparation for competition' for the majority of players but are not generally altered by regular training and match-play. Such findings would seem to suggest that the majority of players are able to adequately manage energy balance in competition. They are also useful in helping inform the development of time efficient and effective monitoring strategies within elite football environments.

Previous research has demonstrated that skinfold thickness in elite male footballers is likely to change during a season as a result of training, match play, diet and habitual activity. For example, Milanese et al. (2015) showed that pre-season values were the highest, then declined mid-season but increased at the end-season point. This supports the findings of numerous other studies (Carling and Orhant 2010; Owen et al. 2012; Lago-Peñas et al. 2014; Requena et al. 2017). However, Yargic et al. (2020) did not show any statistically significant changes across the course of a season, though it is important to note that they used 7-site skinfold thickness equations. This highlights the need to be cautious when interpreting and comparing results from investigations which have used different methods of evaluation.

The majority of these studies have made assessments over relatively short time periods. The results of Carling and Orhant (2010), who observed trends in skinfold thickness over three competitive seasons, do seem to support the findings from these single-season studies. For example, Carling and Orhant (2010) demonstrated an increase in body fat levels during the off-season, which are then reduced during the preseason when training volume is usually the highest. The current study demonstrated that, although mean sum8 values showed only minor fluctuations during the competitive phase of the first two seasons, an overall decline was observed throughout the final season. This contradicts previous research (Owen et al. 2012; Milanese et al. 2015). In the current study, the team was competing for its first domestic title in 10 years in 2020/21. Therefore, there was a particular focus on preparation for training and matches that would be different had the team had less to play for. This may have maximised the training stimulus, through mechanisms such as enhanced motivation to train and compete at a high intensity (Anderson et al. 2022).

Interestingly, the highest skinfold thickness occurred at the start of the entire time series. These findings are noteworthy because this time point was the first skinfold assessment taken under a new management and physical performance team. Several factors may explain this. First, a greater emphasis was placed on monitoring body composition as a performance metric and as a result the testing frequency was increased from four times per season to monthly. It may also reflect an imposition of specific pre-defined target zones that were required to be attained by players. On this basis, players may well have altered behaviour and adherence (Hawthorne effect) to these new environmental considerations. This illustrates the importance of environmental factors on body composition. Other changes in the club infrastructure associated with refinements to support a high-performance training environment may also have been important. For example, the club kitchen was redesigned and a new, periodised menu was implemented. This was supported by periodic knowledge-sharing sessions on the importance of nutrition for body composition and performance. This increased emphasis around nutrition and an awareness of the importance of such factors to performance may have been involved in driving behavioural change in individual players and the group as a whole.

Few studies have investigated the impacts of longer periods of restricted training practice on body composition. The pandemic quarantine period resulted in some major differences to traditional off-seasons, including the enforcement of lockdown, alongside the implementation of social distancing and other restrictions. Consequently, players were required to train both remotely and individually for an extended period to offset the effects of the removal of team-based training and match play on players' health and performance (Anderson et al. 2022). This provides an opportunity to explore how skinfold thickness in elite football players responds to an extraordinary training context. Although negative body composition changes are usually associated with remote training away from the club in professional soccer players (i.e., in the off-season) (Reinke et al. 2009; Suarez-Arrones et al. 2018; Grazioli et al. 2020), our data shows that, in contrast to off-season changes in other seasons, skinfold thickness over the extended COVID-19 intervention period did not significantly increase Taken alongside other results of this training programme (currently unpublished), it would seem that the training and nutritional programme was able to largely maintain all levels of fitness being assessed, including limiting increases in skinfold thickness (Anderson et al. 2022). These data emphasise to practitioners that alternative methods of training can provide players with a sufficient stimulus to maintain in-season fitness levels. This approach to training can be used to complement in-season training (i.e., when time off is prescribed to players) or used throughout periods of non-habitual loading (i.e., off-season, international breaks, and winter breaks). These findings can be attributed to a number of factors such as an extremely structured programme, consistent remote support, smaller coach-to-player ratio and no definitive start date, which probably gave an edge to training as players were unable to switch off. The enforcement of lockdown rules meant there was temporary closure of restaurants, cafes and non-essential retail shops, with no holidays also limiting opportunity to engage in poor dietary behaviours.

The data in this investigation may be impacted by a number of limitations. Previous studies have explored positional differences in body composition measures in elite soccer players (Carling and Orhant 2010). Positional differences in skinfold thicknesses, whereby strikers and defenders have the highest and midfielders the lowest, have been demonstrated (Milanese et al. 2015; Bilsborough et al. 2016; Devlin et al. 2017). In the current study, robust analyses of between-group differences and, in turn, interpretation was not possible due to a low sample size among particular positional groupings. The figures presented in this study provide insights at both an individual player and group level, and our linear mixed models accounted for inter- and intra-individual variations. Further interrogation of model outputs at the individual level would provide a more nuanced understanding of intra-individual changes across seasons and time points. However, this was not the primary purpose of this research study; such insights are particularly relevant to the practice context (Buchheit 2016).

Another limitation of this study was the lack of data on match and training activity. Understanding the activity profiles of these football-specific sessions would provide an indication of the energy expenditure required to support the performance. These estimations would have enabled the relationships between the changes in skinfold thickness and activity to be explored.

Conclusion

This study has demonstrated that there are notable changes in skinfold thickness between key seasonal time points among a squad of elite male football players, particularly during periods of intensive training (i.e., pre-season) or reduced training ground exposure (i.e., off-season). However, mitigation of increases in skinfold thickness during the COVID-19 lockdown among this group shows that adherence to prescribed remote training and diet can be used to manage the size of these seasonal changes. Taken together, these findings have important relevance for sports science/sports medicine practitioners working in this area. The inclusion of regular measurements of body composition for players in squads seems important, though the specific frequency of these measurements should be guided both by specific contextual factors (objectives of the teams performance plan, stage of the season etc.) and the individual needs of players. The results also highlight that it is possible to influence players using techniques (such as on-line support) that are not frequently employed within the sport. This has the potential to provide a platform to create new strategies to develop high performance behaviours across all playing populations.

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