



Original research

No sport for old players. A longitudinal study of aging effects on match performance in elite soccer

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ARTICLE INFO

Article history:

Received 17 November 2021

Received in revised form 2 March 2022

Accepted 7 March 2022

Available online 9 March 2022

Keywords:

Age

Soccer

Positional roles

Performance analysis

ABSTRACT

Objectives: This study aimed to examine the effects of age on match-related physical and technical–tactical performance in elite soccer players using a longitudinal design.

Methods: Data were collected from 154 players who competed in the Spanish first division (LaLiga) between the 2012–13 and 2019–20 seasons. A total of 14,092 individual match observations were analyzed using a computerized tracking system (TRACAB, Chyronhego, New York, NY). The players were classified into five positional roles: central defenders ($n = 37$); external defenders ($n = 44$); central midfielders ($n = 34$); external midfielders ($n = 22$); and forwards ($n = 17$).

Results: The main results showed that (a) soccer players decreased by an average of 0.56% their total distance covered for each year that they got older. Similarly, the number of high-intensity efforts and distance covered at high-intensity running decreased by 1.80% and 1.42% per year, respectively; (b) players significantly increased their pass accuracy by an average of 0.25% each year that they got older; (c) the detrimental effect of age on total distance and high-intensity running was greater for external defenders, external midfielders, and forwards; and (d) the positive effect of age on pass accuracy was greater for central defenders and central midfielders.

Conclusions: Elite soccer players with long-term careers were unable to maintain their match-related physical performance as they got older. However, players can annually improve their technical–tactical skills with increasing age as a possible compensation mechanism against physical performance declines related to aging.

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Practical implications

- TD and HIR efforts during training and matches in professional soccer players should be regularly monitored and analyzed, because this could provide reliable insight into players' performance intra-individual changes with aging.
- Better technical–tactical performance (i.e. PA) observed in older players could suggest a compensation mechanism to extend their careers. This information could be used by managers and coaches to guide decisions regarding contract policies, such as salary, the duration of the contract, or when to transfer or replace a player.
- ED, EM and F are the playing positions most affected by increasing age. Thus, this information may be useful for strength and conditioning specialists in order to individualize training plans and training load during a microcycle, and develop age-tailored programs.

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1. Introduction

The aging process plays a critical role in determining the competitive performance of top athletes. Several studies have confirmed annual increases in age of peak since the year 2000 in different elite sports.¹ Elite athletes are getting older and probably this fact may have a significant consequence for the business of sport. Knowing when players are performing at their best and understanding the effects of age on match-related physical and technical–tactical performance could help coaches, players and soccer club managers to make better decisions in their daily work.²

Elite soccer players finish their sport career between the ages of 31 and 35, with an average career duration of 8 to 11 years.³ Several studies have identified that the peak age of performance in the most important soccer leagues varied between 25 and 27 years, depending on position.^{2,4} Forwards peak (at approximately 25 years) earlier than midfielders and defenders (at approximately 27 years).^{2,4} Additionally, recent studies examining match physical performance showed that

players over 30 years perform significantly lower in the total distance covered, high-intensity activities, sprint distance and the number of accelerations and decelerations.^{5–9} These age-related physical performance declines are more pronounced among central defenders, central midfielders and forwards. However, very few studies have studied the changes in technical–tactical performance of elite players according to their chronological age. These studies found that the number and the percentage of successful passes are significantly higher in older players (>30 years) compared to younger age groups (<30 years).^{8,9} Again, the technical–tactical performance-related parameters showed different trends depending on the playing position.

To the best of our knowledge all previous studies are based on cross-sectional designs; hence findings may have been influenced by cohort problems, such as differences in skill factors, lifestyle or genetics.⁷ There has been no research examining longitudinal player performance in elite soccer. Thus, it is reasonable to assume that probably players leave elite soccer when their performance starts to decline, and that only the players that are genetically gifted or highly skilled participate beyond a certain age and have longer careers.⁷

Taking into account all previous considerations, the current study aimed to analyze the effects of age on match-related physical and technical–tactical performance using a longitudinal design. We hypothesized that while the running performance of players decreased with advanced age, the technical–tactical performance is not related with increased age in elite soccer, and that these effects would be different across playing positions.

2. Methods

Data were collected from 154 professional soccer players who competed in the Spanish first division (LaLiga) between the 2012–13 and 2019–20 seasons. Players' inclusion criteria were the participation in at least five entire matches (i.e. 90 min) for at least five seasons.¹⁰ In addition, all observations from matches which included a player dismissal were excluded. Thus, a total of 14,092 individual match observations were analyzed, with a mean of 15.2 ± 7.0 observations per player and season. The distribution of match observations according to season and playing position is shown in Table 1. In line with previous studies,¹¹ all players and corresponding match observations were classified into five positions: central defenders (CD; $n = 37$ players, match observations = 3769), external defenders (ED; $n = 44$ players, match observations = 4233), central midfielders (CM; $n = 34$ players, match observations = 3281), external midfielders (EM; $n = 22$ players, match observations = 1535), and forwards (F; $n = 17$ players, match observations = 1274). This classification was computed by operators of LaLiga based on players' activity on the pitch and the primary area where this activity was performed.¹¹ Players' age for each season was determined according to their year of birth. Data were obtained from the Spanish Professional Soccer League (LaLiga), which authorized the use of the variables included in this study. In accordance with LaLiga's ethical guidelines, this investigation does not include information that identifies the players.

Match running performance was examined considering the total distance (TD) covered by players, as well as their distance covered at high-intensity running (HIR; $>21.0 \text{ km} \cdot \text{h}^{-1}$). The number of efforts

made at high-intensity running (N of HIR) was also gathered. Absolute values of these physical variables were normalized to relative values per unit of time in order to account for the possible differences in the total playing time of matches. Players' technical–tactical performance was analyzed according to their pass accuracy (PA), defined as the percentage of successful passes over the total number of passes attempted. All these data were recorded using the multicamera computerized optical tracking system TRACAB (Chyronhego, New York, USA), managed from the Mediacoach software (LaLiga, Madrid, Spain). The validity and reliability of TRACAB and the Mediacoach system have been recently described.¹²

In addition, three situational variables were recorded for each individual match observation: match outcome (loss, draw, or win), match location (home or away), and the numerical difference between the end-of-season rankings of the two competing teams (for example, if the team ranked 1st in the season plays against the team ranked 10th, the value of this variable for the players of the first team would be -9 , while for the players of the second team it would be 9).¹³

Statistical analyses were conducted using the software R version 4.0.3.¹⁴ Linear mixed models were adjusted using the R package *lme4*¹⁵ in order to analyze the effects of age on players' match performance according to playing position (Age \times Playing Position). The situational variables match outcome, location, and ranking difference were also fitted as fixed effects. Players' ID was modeled as a random effect to account for the repeated measurements. In addition, each season was also fitted as a random intercept in order to take into account the evolution of physical and technical–tactical performance across seasons. The assumptions of homogeneity and normal distribution of the residuals were verified for each model, without revealing specific problems. The Wald chi-square (χ^2) test was performed to analyze the fixed main and interaction effects using the package *car*.¹⁶ Marginal and conditional R^2 metrics are also provided for each model. For all analyses, the significance value was set at $p < 0.05$.

3. Results

Table 2 shows the standardized regression coefficients for each model, while the effects of age on players' match performance are depicted in Fig. 1. According to the results of the Wald test, significant effects of age were obtained for all performance variables, that is, players' TD covered ($\chi^2 = 21.98$; $p < 0.001$), distance covered at HIR ($\chi^2 = 21.89$; $p < 0.001$), N of HIR ($\chi^2 = 12.37$; $p < 0.001$), and PA ($\chi^2 = 7.09$; $p = 0.008$). More specifically, soccer players were found to decrease their TD covered by an average of 0.56% for each year that they got older. Similarly, HIR and N of HIR were shown to decrease by 1.80% and 1.42% per year, respectively. In contrast, players' PA increased by 0.25% per year.

Fig. 2 shows the effects of age depending on the playing position. Overall, significant interaction effects between age and playing position were obtained for the variables TD ($\chi^2 = 43.82$; $p < 0.001$), HIR ($\chi^2 = 57.39$; $p < 0.001$), and PA ($\chi^2 = 12.58$; $p = 0.014$). With regard to TD, the effects of age were greater for ED, EM, and F, who decreased their TD covered by 0.58%, 0.81%, and 0.64%, respectively, for each year that they got older. Conversely, this decrement in TD covered was lower for CD (0.40%) and CM (0.37%). Likewise, ED, EM, and F showed greater

Table 1
Distribution of match observations according to season and playing position.

	2012–13	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20
CD	349	413	520	569	545	540	504	329
ED	379	531	652	601	512	606	578	374
CM	340	388	408	443	451	475	416	360
EM	143	185	234	201	186	211	219	156
F	129	137	120	171	169	234	198	116
Total	1340	1654	1934	1985	1863	2066	1915	1335

Table 2
Standardized regression coefficients.

	TD		HIR		N of HIR		PA	
	β (SE)	<i>p</i>	β (SE)	<i>p</i>	β (SE)	<i>p</i>	β (SE)	<i>p</i>
Intercept	-0.70 (0.11)	<0.001	-0.60 (0.09)	<0.001	-0.63 (0.10)	<0.001	0.50 (0.09)	<0.001
Age	-0.13 (0.04)	0.002	-0.08 (0.03)	0.020	-0.12 (0.04)	0.003	0.10 (0.03)	0.003
Playing position (CD)								
ED	0.69 (0.13)	<0.001	1.22 (0.12)	<0.001	1.21 (0.12)	<0.001	-0.52 (0.11)	<0.001
CM	1.51 (0.14)	<0.001	0.25 (0.13)	0.049	0.29 (0.13)	0.025	-0.06 (0.12)	0.638
EM	0.86 (0.15)	<0.001	1.40 (0.14)	<0.001	1.39 (0.15)	<0.001	-0.64 (0.14)	<0.001
F	0.53 (0.17)	0.002	1.13 (0.16)	<0.001	1.18 (0.16)	<0.001	-0.91 (0.15)	<0.001
Age × ED	-0.07 (0.02)	<0.001	-0.11 (0.02)	<0.001	-0.02 (0.02)	0.472	-0.07 (0.03)	0.014
Age × CM	-0.01 (0.02)	0.689	0.02 (0.02)	0.404	0.03 (0.02)	0.217	0.03 (0.03)	0.409
Age × EM	-0.15 (0.03)	<0.001	-0.12 (0.03)	<0.001	-0.05 (0.03)	0.118	-0.04 (0.04)	0.275
Age × F	-0.09 (0.03)	0.003	-0.14 (0.03)	<0.001	-0.04 (0.03)	0.208	-0.04 (0.04)	0.347
Match outcome (loss)								
Draw	0.04 (0.01)	0.002	-0.04 (0.01)	0.004	-0.05 (0.01)	0.002	-0.22 (0.02)	<0.001
Win	0.06 (0.01)	<0.001	-0.06 (0.01)	<0.001	-0.05 (0.01)	0.001	-0.17 (0.02)	<0.001
Location (home)								
Away	-0.03 (0.01)	<0.001	-0.10 (0.01)	<0.001	-0.08 (0.01)	<0.001	-0.16 (0.01)	<0.001
Ranking difference	0.02 (0.01)	0.003	0.01 (0.01)	0.243	0.01 (0.01)	0.071	-0.09 (0.01)	<0.001
Random effects (σ^2)								
Player	35.25		1.48		0.01		30.10	
Season	2.22		0.04		0.00		0.63	
Residuals	31.05		2.12		0.01		74.53	
Marginal R ²	0.34		0.35		0.33		0.12	
Conditional R ²	0.70		0.62		0.63		0.37	

detrimental effects per year on HIR (1.99%, 1.96%, and 2.32%, respectively) in comparison with CD and CM (1.37% and 0.89%, respectively). Regarding PA, CD and CM increased their performance by 0.34% and 0.43% for each year that they got older. These positive effects of age were lower for ED (0.10%), EM (0.20%), and F (0.21%). However, no

significant differences were obtained between playing positions for the effects of age on the N of HIR ($\chi^2 = 9.15$; $p = 0.057$). CD decreased their N of HIR as they got older by 1.74% per year, while similar decrements were found for ED (1.27%), CM (1.15%), EM (2.16%), and F (1.52%).

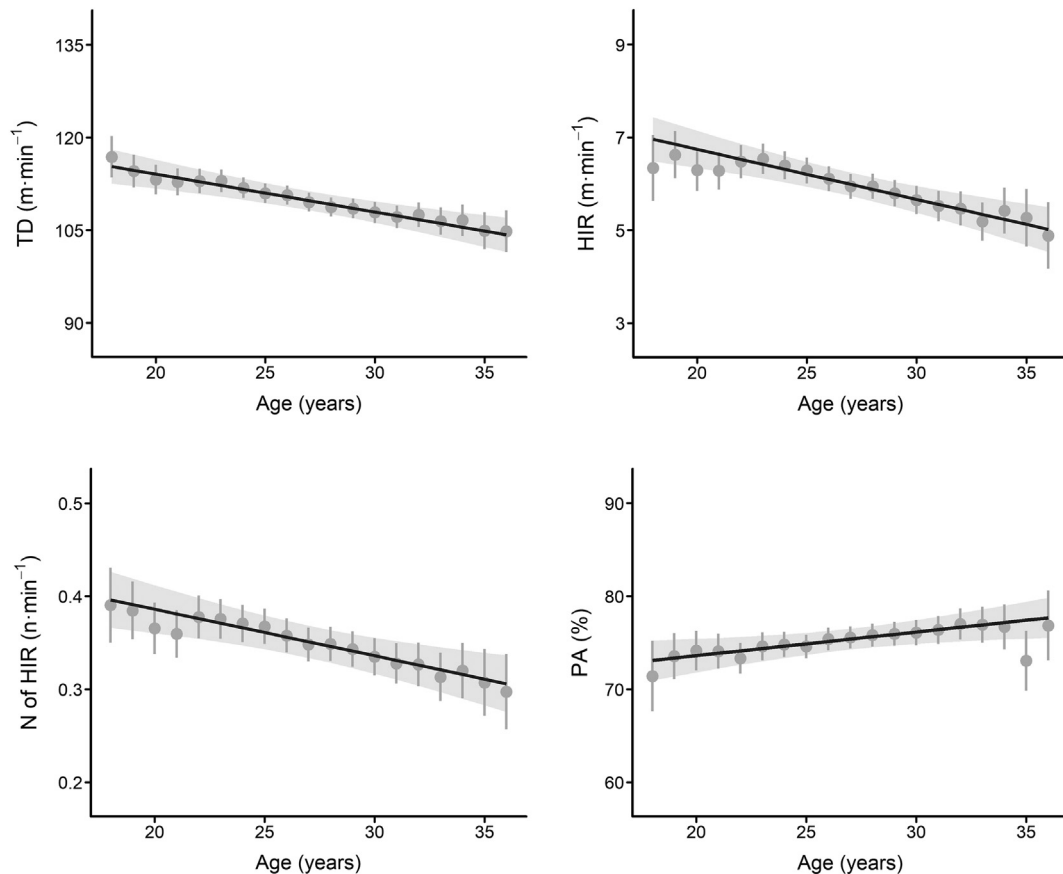


Fig. 1. Effects of age on players' total distance (TD), high-intensity running distance (HIR), number of high-intensity running efforts (N of HIR) and pass accuracy (PA). Data represents the mean and 95% confidence intervals.

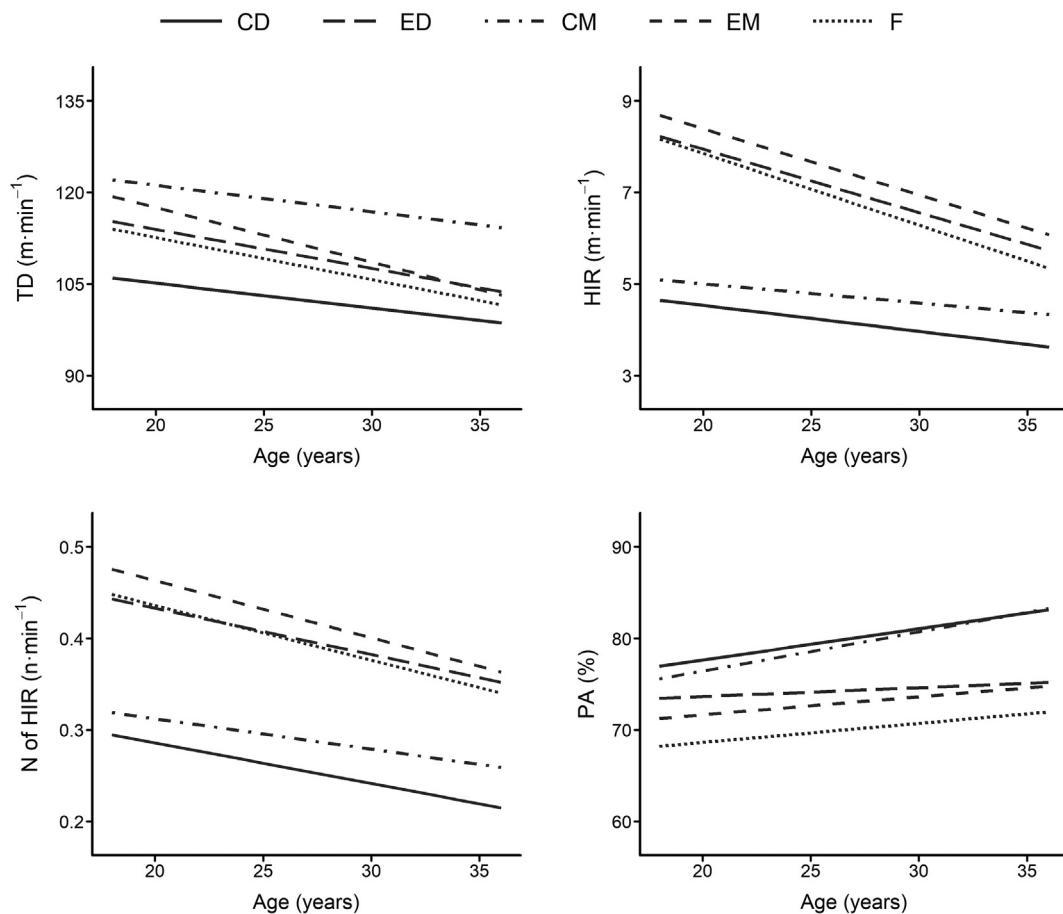


Fig. 2. Effects of age on players' total distance (TD), high-intensity running distance (HIR), number of high-intensity running efforts (N of HIR) and pass accuracy (PA) depending on the playing position.

4. Discussion

This study aimed to analyze the changes in match-related physical and technical-tactical performance that occur as a result of age in professional soccer players across different playing positions. According to the results, the main findings were that: (a) elite soccer players significantly decreased by an average of 0.56%, 1.42%, and 1.80% the TD, N of HIR, and HIR respectively, each year that they get older; (b) elite soccer players significantly increased their PA by an average of 0.25% each year that they got older; (c) the detrimental effect of age on TD and HIR were greater for ED, EM, and F; and (d) the positive effects of age on PA were greater for CD and CM.

As a result of a growing scientific interest, several recent studies have investigated the relationship between age and match performance in elite soccer players.^{5–9} Using cross-sectional approaches, these previous studies generally showed age-related decreases of match-running performance in professional-elite older players (>30 years), increasing the body of evidence in this field. However, to the best of our knowledge, there are no studies that have analyzed the effects of aging on match-related performance of elite soccer players using a longitudinal design. Consequently, this study could provide a more reliable and powerful insight players' performance intra-individual changes with aging.¹⁷

The TD covered in soccer matches has been extensively studied as an indicator of the overall physical demands during elite competitions.¹⁸ The current results show that players exhibit an almost linear significant decrease in the TD by an average of 0.56% for each year that they get older. These results are mostly in line with previous cross-sectional studies that have concluded a significant decrease in match TD performance with increasing age in soccer players from the Bundesliga,⁸ LaLiga,⁷ and the Chinese Soccer Super League.⁹ Previous studies in

soccer revealed significant strong correlations ($r = 0.89$) between maximal oxygen uptake (VO_{2max}) and TD covered during matches.^{19,20} Thus, from a physiological perspective, it is likely that the linear decrement of TD could be explained by the decrease in aerobic function observed in the third decade of life,²¹ confirmed in soccer players by Botek et al.,²² who reported significant age-related declines of relative VO_{2max} in elite players.

High-intensity efforts are considered one of the most essential physical actions in elite players, due to their importance in decisive offensive situations (i.e., in scoring and assisting a goal) in soccer.²³ The present results showed annual age-related decrements of HIR (−1.80% per year) and N of HIR (−1.42% per year) started at ≈23 years until the end of players' careers in LaLiga. These findings are mainly in accordance with those reported in previous studies,^{7,8} which showed decrements of the HIR and N of HIR (−12%) in professional soccer players >30 years. The decline of HIR efforts observed in the early-to-mid 20s might be associated with diminishing soccer-specific physical abilities,²⁴ and/or age-related changes in neuromuscular and mechanical properties,²⁵ such as decrease in muscle strength,²⁶ or cross-sectional area and number of fast-type-II fibers.²⁷ However, future studies should include fitness data obtained by regular soccer evaluations in order to clarify the relationship between the decline of the physical match performance and physical fitness.

PA is considered an important indicator in soccer success, as it captures players' global technical-tactical performance.²⁸ In contrast to those observed in physical performance variables, the present results showed an annual age-related improvement of PA by an average of 0.25% for each year that players get older. These results are in agreement with previous studies in elite soccer players,^{7,8} and seem to indicate that players with large careers in LaLiga can improve their technical-tactical skills and/or

decision-making abilities as they get older.⁸ These findings may illustrate a possible compensation mechanism for declining match-related physical performance by improving game intelligence and tactical awareness,^{7,8,29} which may help players to remain in higher ranking leagues like LaLiga. In this sense, scientific literature revealed that Spanish LaLiga has a more possession-based playing style and teams are more likely to score a goal after utilizing longer possessions (12 s) compared with other European competitions.^{30,31} Thus, the age-related compensatory increase in PA observed in the present study may have important practical implications as PA remains a strong predictor of success in LaLiga and could represent an age-specific evolution for players in this competition.

The findings of the present study also support the hypothesis that physical performance and technical–tactical performance show different age-trends depending on the playing positions. Specifically, CD and CM were less affected by the detrimental effect of age on TD and HIR. This finding could be expected because CD and CM are the less demanding playing positions in terms of HIR efforts.³² In addition, the positive effects of age on PA were greater for CD and CM compared with ED, EM and F. These findings may be related to the importance of maintaining pass performance in modern soccer for the CD and CM necessary to extend their careers in LaLiga.^{4,7}

Considering the limitations of the current study, some aspects should be highlighted: (1) Player positions were manually computed based on players' activity on the pitch, which could lead to some categorization bias; (2) running distances by intensities were not normalized based on individual players' performances; (3) other confounding variables such as the team ability, the number of matches played by season or the impact of the coach replacement on physical and technical–tactical performance could be added in future studies; and (4) finally, the effect of playing behind closed doors in the 2019/2020 season was not considered.

5. Conclusions

In summary, this study provides new evidence on the relationship between match performance in elite soccer and aging effects using a longitudinal design. Players with long-term careers were unable to maintain their physical performance as they got older. However, players can annually improve their technical–tactical skills with increasing age, as a possible compensation mechanism against physical performance declines related to aging. The detrimental effects of age on physical performance were greater for ED, EM, and F, while the positive effects of age on PA were greater for CD and CM.

Funding information

Funding for open access charge: Universidade de Vigo / CISUG.

Declaration of interest statement

All authors declare they have no conflict of interest.

Confirmation of ethical compliance

In accordance with LaLiga's ethical guidelines, this investigation does not include information that identifies the players.

Acknowledgement

No acknowledgments are required.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jsams.2022.03.004>.

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