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Variations of estimated maximal aerobic speed in children soccer players and its associations with the accumulated training load: Comparisons between non, low and high responders

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A R T I C L E I N F O

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A B S T R A C T

The aim of this study was twofold: (i) to examine the variations of estimated maximal aerobic speed between non, low and high responders and (ii) to analyze the relationships between accumulated training load parameters and variations of maximal aerobic speed in children soccer players. Forty-four male soccer players were assessed three times during the early and mid-season (second to fifth month of the season) and were monitored daily over the period of analysis using the rating of perceived exertion (RPE), recording the training duration (in min) and calculating the session-RPE (sRPE). Pairwise comparisons revealed that maximal aerobic speed (MAS) was greater for the third assessment than the first (*p-value* [p] = 0.003; *standardized effect of Cohen* [d] = 0.355) and second (p = 0.013; d = 0.193) assessments. Large correlations were found between MAS and accumulated RPE, accumulated time, and accumulated sRPE. Moreover, non, low and high responders differed in ΔMAS ($p < 0.001$) with the last group presenting the largest improvement in MAS. Results suggest that children with lower MAS baseline levels will improve more this capacity over the early and mid-season period compared to children with better baseline levels. Moreover, associations between accumulated training load and MAS were found, suggesting that the training effort can be related with aerobic capacity changes.

1. Introduction

Soccer can be characterized as an intermittent sport, with multiple short and very high intense actions interspaced by low-activity demands [1,2]. Therefore, soccer players depend on a well-developed aerobic and anaerobic systems that allow to sustain high-intensity efforts with intermittence during 90 min [3,4]. Naturally, aerobic capacity is one of the fundamental fitness components of soccer players allowing covering between 9 and 12 km in which 1000–1500 m are performed at high speed running (> 19.8 km/h) and sprinting (>25 km/h) [5]. In the case of children at the beginning of puberty, maximal oxygen uptake in matches may vary from 50 to 64 mL/Kg/min [6] while physical demands imply ~6500 m in which ~670 is made at high-intensity running and ~300 at very high intensity running [7].

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Also, in children soccer players, it seems that VO2 kinetics are related to physical measures associated with soccer matches [8], thus justifying the pertinence of a well-prepared aerobic capacity even in children.

Aerobic capacity is one of the topics of great interest to researchers in sports sciences [9]. Among other indicators, maximal oxygen uptake (VO_2max) or maximal aerobic speed (MAS) are some of the core variables that may determine the intensity of exercise and make possible to track the aerobic changes of the players across training periods [10]. In the particular case of soccer, the aerobic performance is one of the determinants of physical qualities and can be associated with a better capacity to sustain high effort levels and short recovery during matches [11]. Moreover, good aerobic performance is fundamental for players to withstand long training sessions and matches [12]. Additionally, it has useful effects on several parameters during the match, such as the number of sprints, the number of interactions with the ball, total time spent on high-intensity activities [7] based on the capacity to optimize the recovery during low demanding periods of time [13].

The evidence about aerobic capacity changes in professional soccer players or elite youth players during the season is well-described [14,15]. However, the findings in children players are now so well-described. Boraczynski et al. [16] reported decreases in relative VO_2max in children after a 2-year training period. In contrast, Alves et al. [17] reported that 8 weeks of intrasession aerobic and strength training increase VO_2max by around 7.3% (this value is 3.8% for children between the ages of 10 and 12 years old). Therefore, monitoring physical readiness parameters in the early ages is a meaningful aspect of the training process because it is an important period of physical development [18]. Consequently, it is necessary to understand and manage all situations and characteristics which can both increase and decrease sports performance to support coaches' short- and long-term decisions [19,20]. Naturally, that fluctuations in aerobic capacity should be also interpreted based on some concurrent factors. In fact, sensitiveness of aerobic changes may be dependent, among others, of the moment of the season, the baseline level of the players or the training load imposed [21].

The association between changes in aerobic capacity and training load promoted by coaches have been reported in professional players [22,23]. Results have been found that there is a positive and meaningful association between the accumulated training load and the improvements in aerobic capacity [24]. The training load can be measured at different levels (internal and external), however, there is a consistent report in the literature about the validity and reliability of perceived exertion scales to quantify the load comparing to objective measures like heart rate or even comparing with GPS-derived measures [25,26]. Despite the importance, the dose-response relationships studied in soccer has not being centered in children players and there is a lack of information about the interaction between the accumulated training load and the changes in cardiorespiratory fitness. In particular, there is a lack of evidence about training intensity occurring in pre-adolescent players, as well as, identification of how these players vary aerobic performance across the season. In fact, children are characterized by a weaker anaerobic capacity and similar aerobic capacity compared to with adults [27]. Thus, and considering the aerobic metabolism as primary pathway, it seems relevant to monitor eventual variations across a season.

Moreover, commonly VO_2max is reported as the aerobic capacity indicator in soccer. However, other key aerobic measures as MAS has been not properly described. This key trait may also be a determinant of soccer performance, namely because determine the threshold velocity of the players before the anaerobic velocity reserve and this may characterize the trainability level of the players and may be a good indicator of performance [28]. Currently, there are few studies that reported the evolution of such parameter in children soccer players [29]. Moreover, considering that baseline levels may influence the aerobic capacity changes across the season, it would be important to know more about the influence of aerobic baseline levels on the capacity to be a non, low or high responder to training and its relation to volume and intensity, like has been studied in elite players [22]. Therefore, the aim of this study was twofold: (i) to examine the variations of estimated MAS between non, low and high responders in the early and mid-season and (ii) to analyze the relationships between accumulated training load parameters and variations of MAS in children soccer players.

2. Materials and methods

2.1. Participants

Forty-four male children soccer players (age: 8.33 ± 1.18 years; soccer experience: 1.22 ± 0.43 years; body mass: 31.1 ± 5.9 kg; height: 131.7 ± 6.5 cm) belonging to three different under-10 Portuguese teams participated in this study. The teams were chosen by convenience (proximity between them in terms of geographical distribution) and relationship with the entity responsible to conduct the study. The three teams participated in the same regional competition and presented similar table classifications at the end of data collection (3rd, 5th and 6th classified with a difference of 5 points between the 3rd and the 6th place). The sample included 6 goalkeepers, 12 defenders, 10 midfielders, 8 fullbacks, and 8 forwards. The player's characteristics can be found in Fig. 2 and Table 2. Usually, the children have trained 3 times a week (approximately 70 min each training) plus one match each weekend (50 min per match).

Players were included based on the following criteria: they must have (i) participated in a minimum of 90% of the training sessions that occurred during the period of analysis; (ii) participated in the three assessments applied during the period of analysis and had their RPE measured after all training sessions; (iii) participated in half of matches occurred in the period of analysis (and at least half of the time of each match); (iv) not been involved in any other competitive or recreational sports; (v) not suffered from an injury longer than 3 days or illness during the period of analysis; and (vi) started the season at the same time as the other participants. The size of the sample was calculated to ensure an alpha of 0.05 and a beta of 0.08 using the GPower software 3.17 (GPower; University of Dusseldorf, Dusseldorf, Germany). The result indicated a sample of 37 which is less than we have included (N = 44).

The participants and their parents were informed about the study design as well as the benefits and potential risks of participating. The parents were then invited to sign an informed consent document and both parents and children gave their assent before any of the tests were performed. The participants were free to leave the experiment at any time. The study was approved by a local ethical committee (code number: IPVC-ESDL181002). The study followed the ethical standards of the Declaration of Helsinki for the study in humans.

2.2. Experimental approach

A descriptive case report study using a repeated-measures design to compare the estimated MAS (and its change) of children soccer players across the early and middle of the season (4 months of the season). Players were split by non, low and high responders based on ΔMAS, considering the following criteria: (i) non responders (n = 13, ΔMAS ranged from −13.46 to −0.36% after the season); (ii) low responders (n = 19, ΔMAS 0.32 to 8.89% after the season); and (iii) high responders (n = 12, ΔMAS 12.92 to 37.03% after the season). Training load parameters were monitored daily in all training sessions (50 training sessions) that occurred between assessments during the study. A correlational study was used to test the relationships between accumulated load and performance in the second and third assessments. The study timeline can be found in Fig. 1. The first assessment was performed one month after the beginning of the season (early November), the second assessment occurred in early January (2 months after the

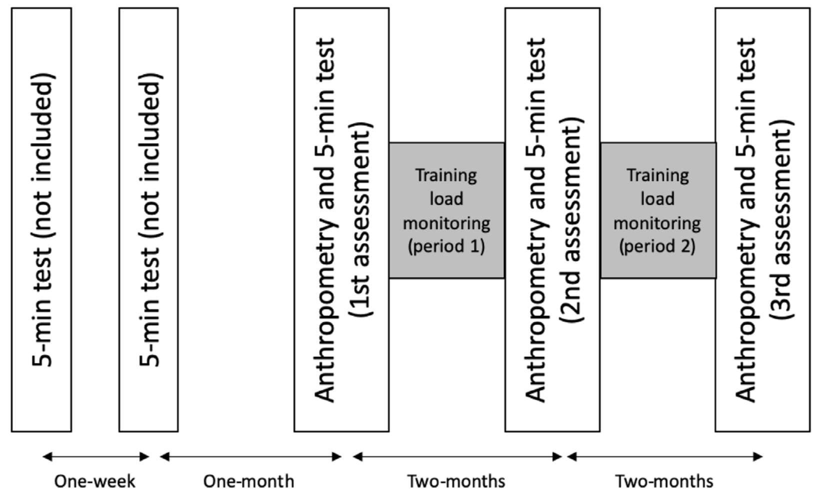

Fig. 1. Study timeline.

first assessment), and the third assessment in early March (two months after the second assessment). The training load was monitored in between the assessments. The period 1 of training load occurred between the first and the second assessment. The period 2 of training load monitoring occurred between the second and third assessments. The training load monitoring included the rating of perceived exertion (RPE), training time records, and the session-RPE (sRPE) calculations (detailed information is given in the methods). The three assessments occurred 72 h after the last match or training session on the same day of the week and at the same time of day. The assessments of anthropometrics occurred in the morning (9.30 a.m.; 23 °C; indoors). The cardiorespiratory fitness tests were conducted in the afternoon (17.30 p.m.; 16.2 ± 1.4 °C; outdoors on synthetic turf).

Note: 5-min test correspond to the test to estimate the MAS. The first two measurements with the 5-min test (not included) were performed only as familiarization sessions with the test

2.3. Assessments

The anthropometric assessments included measurements of height and body mass. A stadiometer (model 213, SECA) was used to measure the height of participants. Two trials were performed by the same observer to ensure the accuracy of the data. The same procedure was performed to measure body mass (BM). A calibrated body scale (model 761, SECA) was used to measure the BM of the participants. Three observers who were previously tested for accuracy collected the data. Body mass index (BMI) was calculated for each participant.

Participants’ cardiorespiratory fitness levels were tested using the 5-min test, previously validated for MAS assessment [30]. Players were familiarized with the test at the beginning of the season (two experimental assessments with difference of one week) and instructed to keep the highest speed as possible at a stable level (and avoid fluctuations in the speed of running during the test). During such experimental period (not included in our results) a test-retest was conducted to quantify the reliability of the 5-min in the population after 3-min of jogging and 5-min of dynamic stretching. The results of intra-class correlation were very good (ICC = 0.93), confirming the reliability of the test. During the three assessments, the 5-min test was preceded by a standardized warm-up consisting of 3-min of jogging and 5-min of dynamic stretching. The test was performed immediately after the warm-up protocol. The test occurred on a synthetic turf field. The track was marked in ten-meter intervals to make it easier to measure the distance covered by each participant. The test was recorded by a digital camera (Go Pro-Hero, 2018, 25 Hz, USA) so that the distance covered by each player could be precisely determined. The distance covered by each player (in meters) was divided by 300 s (5-min) to estimate the player's MAS [31]. Considering the test has no changes of direction (differently from shuttle run-based tests) no correction equation was added.

2.4. Training load monitoring

The CR-10 Borg's scale (Borg, 1998) was used to monitor the RPE of participants during the period of analysis. The players were familiarized with the scale for one month (starting at the beginning of the season) to improve the accuracy of the scores. A visual analogue scale was also built and introduced to improve the player's perception for the 10-point scale. The scale was presented to each player individually approximately 30 min after the end of each training session. The same observer presented the scale to all players and collected each player's scores. This observer also collected the time of each training session (in min). The sRPE, calculated by multiplying the CR-10 score by the time of the session (in min) [32], was calculated for each player.

The training load measures (RPE on the CR-10 scale, time of the session, and sRPE) were used to determine the accumulated load over the period of analysis 1 (between the first and the second assessments) and period of analysis 2 (between the second and the third assessments). The accumulated load was the sum of the results of each training load measure recorded during the period of analysis.

2.5. Statistical procedures

The descriptive statistics is presented in form of mean and standard deviation in both figures and tables. The normality and homogeneity of the sample was tested and observed by using Kolmogorov-Smirnov test ($p > 0.05$) and the Levene's test ($p > 0.05$), respectively. Considering the preliminary assumptions, a one-way ANOVA with repeated measures was executed to analyze the variations of anthropometrics and cardiorespiratory fitness between the three assessments. The Mauchly's test was used to determine the sphericity of the data. Every time that the sphericity of the data was not observed, and the epsilon was > 0.75, we have used the Huynh-Feldt correction. In the case of an epsilon < 0.75, we have used the Greenhouse-Geisser correction. The partial eta squared was also executed to determine the effect size of repeated measures. The pairwise comparisons were tested using the Bonferroni post hoc test and the Cohen's d to determine the effect size. Magnitude inferences according to Cohen's d values were made based on the following thresholds: 0.0–0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; >2.0, very large [33].

The relationships between the cardiorespiratory fitness assessments and the respective accumulated training load in the periods 1 and 2

Table 1
Descriptive statistics (mean and standard deviation) of accumulated training load in the two observed periods (period 1 – trainings between the first and the second assessments and period 2 – trainings between the second and the third assessments).

	Period 1	Period 2
Training sessions (N)	21.3 (6.8)	30.3 (5.5)
Accumulated RPE (A.U.)	125.88 (78.84)	165.44 (78.22)
Accumulated time (min)	1351.77 (811.19)	1810.52 (854.97)
Accumulated sRPE (A.U.)	9937.19 (7976.44)	12,877.19 (8142.79)

RPE: rating of perceived exertion in the CR-10 Borg's scale; sRPE: session-RPE using the Foster's method

were tested using the Pearson r. The magnitudes of the correlation coefficients (r) were interpreted based on the following thresholds [33]: 0.0–0.1, trivial; 0.1–0.3, small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; 0.9–1.0, nearly perfect. Confidence intervals of 95% were used for the correlation values (r). In addition, the percentage change in MAS (ΔMAS) from the first (MAS_1), second (MAS_2) to the third (MAS_3) measurement was calculated using the formula '100 × (MAS_3-MAS_1)/MAS_1′. Then, the participants were classified to three groups, non responders (n = 13, ΔMAS ranged from −13.46 to −0.36%), low responders (n = 19, 0.32 - 8.89%) and high responders (n = 12, 12.92 - 37.03%), based on ΔMAS. The statistical procedures were executed on SPSS software (version 24.0, IBM, USA). Significance was set at $p < 0.05$.

3. Results

The accumulated training load of the two observational periods (period 1: between 1st and the 2nd assessments; period 2: between the 2nd and the 3rd assessments; see in detail in the Fig. 1) can be observed in Table 1.

Descriptive statistics of MAS performance across the three assessments conducted over the season can be observed in Fig. 2. Repeated measures ANOVA revealed significant differences in the 5-min test (p = 0.001; partial eta squared = 0.174) and the respective MAS (p = 0.001; partial eta squared = 0.174) during the three assessments conducted over the season. Pairwise comparisons revealed that the performance in the 5-min test was better in the third assessment in comparison with the first (dif: 49.80; p = 0.003; d = 0.370, small effect) and the second (dif: 24.75; p = 0.013; d = 0.200, small effect) assessments. Moreover, it was also found that MAS was greater in the third than in the first (dif: 0.17; p = 0.003; d = 0.355, small effect) and second (dif: 0.08; p = 0.013; d = 0.193, trivial effect) assessments.

The accumulated training load parameters during the two observed periods were associated with the maximal aerobic speed of the second and third assessments. The correlation coefficients can be found in the Fig. 3. Large correlations were found between MAS and the accumulated RPE (r = 0.62, [0.44;0.75]; p = 0.000), accumulated time (r = 0.63, [0.45;0.76]; p = 0.000) and accumulated sRPE (r = 0.65, [0.48;0.78]); p = 0.000) in the observed period 1 (first two months of training). Similarly, in the observed period 2 (second two months of training) large correlations were found between MAS and the accumulated RPE (r = 0.58, [0.39;0.73]; p = 0.000), accumulated time (r = 0.62, [0.43;0.75]; p = 0.000) and accumulated sRPE (r = 0.63, [0.46;0.76]); p = 0.000).

Non responders, low responders and high responders differed in ΔMAS (p<0.001) with the high responders presenting the largest improvement in MAS (Table 2). They differed in MAS_1, where non responders had higher MAS (+0.60 m/s) than the high responders (p = 0.000; d = 1.858, large effect). No difference in any other variable was observed among these groups (p>0.05). The ΔMAS was significantly greater in high responders comparing to non (p = 0.000; d = 4.568, very large effect) and low responders (p = 0.000; d = 3.620, very large effect).

4. Discussion

In the present study, variations in MAS were analyzed over a season. A greater MAS was found in the third assessment (4-months after the baseline test) than in the first (baseline) and second assessments (2-months after the baseline). Regarding the different groups, high responders presented the greatest improvements (~21%), in opposition to the low responders that showed a decrease in MAS capacity (~4%). Additionally, this study aimed to analyze the relationships between accumulated training load parameters and cardiorespiratory performance. In this regard, large correlations were found between MAS and accumulated RPE, accumulated time, and accumulated sRPE.

The aerobic energy system is essential for coping with long training sessions and soccer matches [16,34]. A healthy aerobic energy system is a distinguishable feature among adult elite players [35]. Nevertheless, even in elite soccer players below 15 and 16 years of age, the aerobic component of fitness was shown to be the most important fitness capacity [36]. Similar results were observed in an younger group (age 14.5 ± 0.4 years) during 8 months of soccer training [37]. However, it should be noted that increases in anthropometric traits, body mass, skeletal muscle mass, heart and lung mass, hemoglobin levels, blood volume, and nervous system maturation may lead to

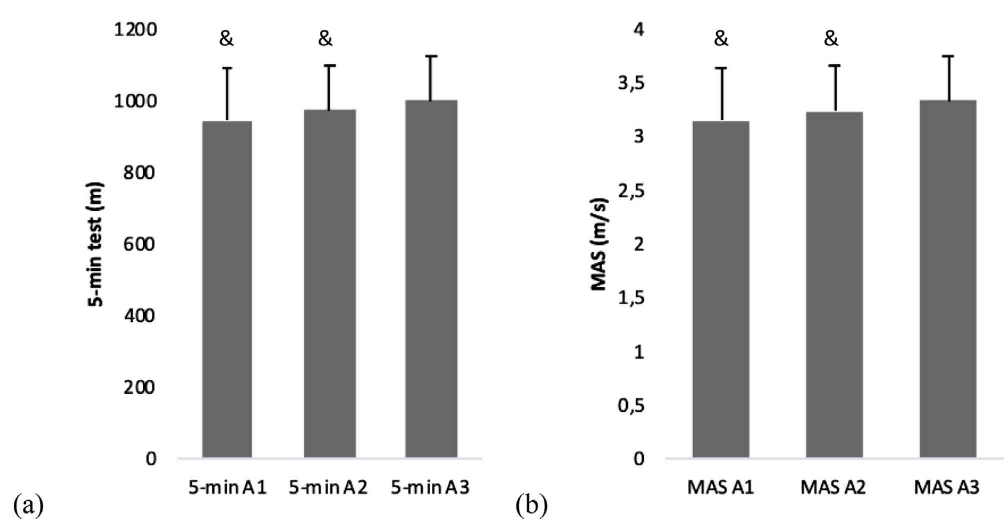

Fig. 2. Mean and standard deviation of (a) 5-min test and (b) maximal aerobic speed (MAS) after 1 month (A1), 3 months (A2) and 6 months (A3).

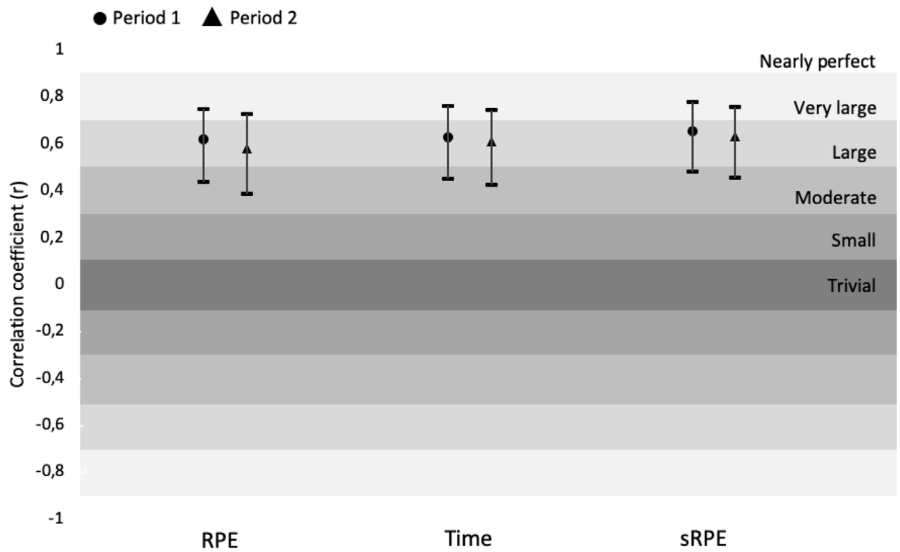

Fig. 3. Correlation coefficients between maximal aerobic speed and the anthropometrics and accumulated training load parameters in the two observed periods (first period – between the first and the second assessment; second period – between the second and the third assessment).

Table 2
Comparison among responders and non responders.

Variable	Non responders (n = 13)	Low responders (n = 19)	High responders (n = 12)
Age_1 (years)	8.62 ± 1.19	8.63 ± 1.30	7.92 ± 0.90
Body mass_1 (kg)	34.1 ± 4.6	31.5 ± 5.6	28.9 ± 6.2
Height_1 (cm)	134.1 ± 6.6	132.5 ± 4.9	129.4 ± 7.8
MAS_1 (m/s)	3.46 ± 0.42	3.14 ± 0.53	2.86 ± 0.16[a]
MAS_2 (m/s)	3.32 ± 0.36	3.21 ± 0.54	3.21 ± 0.18
MAS_3 (m/s)	3.32 ± 0.38	3.25 ± 0.53	3.45 ± 0.17
ΔMAS (%)	−4.15 ± 3.60	3.75 ± 2.52	20.87 ± 6.97[a,b]

MAS = maximal aerobic speed; ΔMAS = change from MAS_1 to MAS_3.
[a] : significantly ($p < 0.05$) different from non responders.
[b] : significantly ($p < 0.05$) different from low responders.

changes in aerobic capacity [10,38]. On the other hand, the low amount of androgen available in a child's body does not contribute as much to cardiac muscle hypertrophy, hemoglobin stimulation, or metabolic enzyme synthesis [39], resulting in low trainability of children between 4 and 12 years of age [40,41]. In fact, it was previously found that relative maximal aerobic capacity and the absolute aerobic power begin to increase several years before the growth spurt and continues to increase after that milestone [38,42]. This suggests that the earlier the development of cardiorespiratory capability is stimulated (according to the player's age), the greater their progression. Thus, early cardiorespiratory development is likely to benefit all players: as they get older, they will need to have high levels of aerobic fitness to cope with the intense weekly training sessions regardless of what playing position they specialize [43].

In the present study, only non responders did not show an improvement in MAS values, presenting a decrease of almost 4%. In opposition, in the high responders group it was observed an increase of almost 21%, and an improvement of almost 4% in low responders from the first to the third moment of evaluation (four months between first and third assessments). Differences among groups may be related to genetic [44,45]. In fact, it is usual to present the mean values of the entire sample, remaining unclear whether missing endurance changes or smaller values of improvement in some participants and some variables are caused by training regimen or they are inherent to the participant [44].

The use of RPE to monitor training load has been widely validated and used in adults in different sports [26,46]. RPE is considered a simple, useful, valid, and inexpensive method for monitoring training load [47]. However, some concerns have emerged among researchers who have observed child soccer players. For example, children may find it difficult to use the RPE measurement scale because of their low level of cognitive development [48]. Nevertheless, studies have shown that children athletes are able to use this scale correctly [49–52]. The present study seems to confirm that capability, since all the parameters used to analyze internal load showed a positive and large correlation with MAS (with the entire sample), indicating that, in general, players were aware of the training effort. However, this relationship seems to be more strengthened when analyzing the high responders group, as they presented a large correlation between MAS and accumulated RPE, accumulated time, and accumulated sRPE, in opposition to the other two groups that presented a small inverse correlation.

One possible limitation of this study is related to the lack of differentiation of field positions. Such differences were noted in previous studies among goalkeepers and other players at a young age [43]. Nonetheless, these studies did not show any such differences in older players (U13 to U15) [53,54]. In this regard, Deprez et al. [34] suggest that the different demands of the field positions assumed at the senior level are not fully developed in soccer players between the ages of 8 and 14 years. Deprez et al. [34] also examined that playing position at those ages could change. Therefore, as suggested previously, development programs in children soccer should be based on changes in parameters over time [55]. Finally, the chose for the 5-min test can be also considered a limitation considering the fact that is a field-based test and no specific for intermittent sports (without changes of direction as shuttle run-based tests). However, the use of continuous running decreases the influence of muscular strength and neuromuscular reactivity [30] and this was the basis for not use a shuttle run-based test.

As a novelty, this study revealed that progressive increases in MAS occurred in high responders across the season, in opposition to low responders, that lowered its values. Those results were largely correlated with perceived effort and training load reported during the sessions. Such fact is relatively new in children of this age and should be emphasized aiming to determine that, possibly, the intensity of the session may partially explain the improvements in the MAS. However, such fact should be carefully analyzed in future studies since RPE is merely one of many different variables that represent the intensity of a session.

5. Conclusions

The main findings of this study are that MAS was significantly improved during the season and that the performance of children players in cardiorespiratory field-based tests was largely correlated with the accumulated training load parameters. Professionals (e.g. fitness trainers, coaches) working with children soccer players should consider analyzing the season aerobic performance and identify the strategies to avoid declines in performance.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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