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Relationship between Variations in the Accumulated Workload and the Change of Direction Ability in Elite Young Soccer Players

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Abstract: Background: The main aim of this study was to evaluate the relationships between training workload (WL) parameters with variations in the change of direction (COD) in under-16 soccer players. Methods: Twenty-seven under-16 elite soccer players were daily monitored for their WL across 15 weeks during the competitive soccer season. Additionally, players were assessed two times for anthropometric measures (weight, height, sitting height and leg length), COD performance (modified 505 test) and maturity offset measured using the peak height velocity (PHV). Results: A correlational analysis was performed to determine the relationship between the variation in COD performance and accumulated WL parameters. Moreover, a regression analysis was executed to explain the variations in the percentage of COD performance considering the accumulated WL parameters and PHV of the season (r = 0.93; p ≤ 0.01) and training monotony during the early-season (r = 0.53; p ≤ 0.05). There were associations between the acute workload during the start of the season and the COD during the end of the season (r = 0.47; p ≤ 0.05). The multiple linear regression analysis showed that 55% of the variation in COD performance between the early and end of season could be explained by the acute or chronic WL, training monotony or strain and the PHV. Conclusions: This information might be useful for practitioners and coaches aiming to improve the COD performance in youth soccer players during an entire competitive season.

Keywords: non-linear sprint; acceleration; football; in-season; maturation; ACWLR; training monotony

1. Introduction

Understanding soccer activity is to reflect on its multiple variables, recognized for being an acyclic modality, which, from the point of view of the movement, can be considered an intermittent activity [1]. In addition, the bioenergetics demand also has a complex nature in soccer, which is based on the use of aerobic and anaerobic pathways to provide energy in multiple game situations [2]. These intermittent moments of prolonged high-intensity exertion highlight the determining role of anaerobic metabolism in soccer player activity [3]. The anaerobic capacity (alactic and lactic) is fundamental for the execution of the main
fundamentals of the game, such as short and high intensity efforts, anaerobic power work (e.g., jumps and kicks) with or without possession of the ball or change of directions (COD) [4]. When comparing movement patterns during the game between adult and youth players, there are no significant differences [5]. However, the physical and physiological characteristics of young athletes are influenced by body development and therefore appear to be different from their adult peers [6]. Considering the relationship between fluctuations in overload and anaerobic power in top young soccer players, it is very important to understand that the ability to work develops throughout life through growth, maturation, training and experience [7]. Therefore, for the development of long-term physical qualities to be observed, it is necessary that athletes be exposed to increasing external training load over time, optimizing adequate recovery. This is one of the strategies for greater control of the entire evolution process, which is that training must be prescribed according to the individual capacity of each athlete, namely according to their physical qualities [8].

As recognized in the literature, there are several key points related to the effectiveness of training, such as the period of the season, the competitive level of athletes and the baseline level or training load imposed [9]. The frequency of CODs is independent of position, leg dominance and anthropometry and occurred equally between the left and right direction and the forwards and backwards direction [10] in elite youth football players; the daily loads accumulated during one week showed a strong and moderate correlation with peak power and the COD at different times of the season [11]; elite players perform significantly \( p < 0.05 \) better on all performance tests than amateur players in both age groups. Interestingly, this investigation showed that the more complex the target exercise, the larger the effect sizes for group differences (squat jump, linear sprint, COD). The squat jump and linear sprint can be useful in talent selection tests batteries to separate competitive levels in youth soccer players [12]; thus, it is pertinent that researchers and trainers understand the factors that can affect performance to improve the training process.

The ability to slow down, reverse or alter motion direction and reaccelerate in a new direction, largely known as COD, is considered critical to performance in many sports, particularly soccer [13].

In this context, muscle mass appears to be a decisive factor in maximum speed, endurance and jumping ability in young soccer players [14]. Moreover, performance improvements also depend on an increase in some characteristics (e.g., weight and muscle mass) [15]. It is very important to understand the maturation status of the young athlete to not affect their harmonious development, as both a human being and athlete. Admittedly, regarding the participation of anaerobic power in soccer performance, this variable of physical fitness has been scarcely studied in young players; however, the increase in this capacity in adolescence has been investigated in young soccer players. As in [16], the young soccer player’s ability to work has been the subject of previous work, which recognized speed, agility, strength and power as important predictors of youth soccer performance [17].

It is very important to develop, use and maintain physical quality in order to succeed in this modality [18]. The COD can mean that at the performance of a movement at maximum speed, this displacement requires a rapid production of energy that occurs essentially via alactic anaerobic metabolism (ATP-CP) [19]. This skill is an important training variable and is therefore, trainable; considering the high physical and mental demands, football is an example of a sport in which the combination of physical and technical attributes (e.g., straight, acceleration or sprinting) can be used as a promotion strategy [20]. During a match, athletes can change direction between 1200–1400 times [21], which makes training the COD ability extremely important. Most sprints in youth games take around 3 s [22].

The goal of COD and the mission of training is to make the player stronger and also faster in the course of a COD. Training strategies are essential for better development of intense activities, and another objective of training is to develop specific qualities related to the modality [23]. For example, plyometric training seems to be an effective strategy to enhance the COD of athletes [24]. Speed training is prescribed in order to promote rapid changes in lower limb strength and, as a consequence, COD performance in high
competition youth and adults [25]. Strength training has reported improvements in COD performance [26]. Hence, training protocols should focus on increasing and maintaining muscle strength and power levels [27]. Finally, controlling the training load in soccer is essential and is a factor that should not be neglected at any time during training, and it seems to be a variable of great interest for the athlete’s development [28]. It is crucial to emphasize and understand the process of these relationships so that coaches and physical trainers can have important knowledge for the management and organization of the training protocol. The purpose of this intervention was to verify the relationships between variations in accumulated workload and the change of direction performance in young elite soccer players.

2. Materials and Methods

2.1. Participants

The participants of this study were 27 elite soccer players and were selected by convenience sampling. Players belonged to the same national under-16 team competing in the national league. They were organized by six central midfielders (CM; age: 15.6 ± 0.2 years; height: 172.1 ± 6.5 cm; weight: 59.9 ± 6.1 kg; peak height velocity (PHV): 1.5 ± 0.5 years), three wingers (WG; age: 15 ± 0.5 years; height: 163 ± 4.1 cm; weight: 54.7 ± 4.1 kg; PHV: 0.5 ± 0.5 years), six defenders (DF; age: 15.4 ± 0 years; height: 172.9 ± 1.8 cm; weight: 60.8 ± 4.5 kg; PHV: 1.4 ± 0.4 years), two forwards (FW; age: 15.4 ± 0 years; height: 170.8 ± 15.9 cm; weight: 55.5 ± 10.6 kg; PHV: 0.7 ± 1.3 years) and two goalkeepers (GK; age: 15.4 ± 0.3 years; height: 172.5 ± 10.6 cm; weight: 61 ± 1.4 kg; PHV: 0.9 ± 1 years). The team performed 57 training sessions and 15 competitive matches. All participants provided written consent subsequent to being informed about the research process. The research protocol followed the principles of the Declaration of Helsinki regarding biomedical research involving human subjects. The study was approved by the Ethics Committee of the University of Mohaghegh Ardabili with number 2020/08/07.

2.2. Sample Power

To compute the obtained power, the t-test family (correlation: point biserial model) sample power was computed a priori. The G*Power tool used the following settings: error probability level in \( \alpha = 0.05 \); effect size = 0.5 [11,29,30]; error probability in \( 1 - \beta = 0.85 \). The current study of 24 participants had an actual power of 86.3%. For the calculation sample power, G*Power software was used (University of Düsseldorf, Düsseldorf, Germany).

2.3. Procedures

Participants were assessed before the start of the competition season on anthropometric measurements, maturity and change of direction ability by the same group of researchers during the complete study, at the same time of the day (8–11 am) on a soccer field.

2.4. Anthropometric

A portable stadiometer (Seca model 213, Hamburg, Germany) was used to measure standing stature when players stood barefoot with feet together and their head in the Frankfort plane. The participants were required to take a profound breath and hold their head until two measures were recorded to a precision of ±5 mm. Almost identical procedures were used to measure sitting height; the participants were asked to sit on the 50 cm height box, facing forwards with their feet together and their hands rested on their thighs.

2.5. How to Calculate Maturation

A portable weighting scale (Seca model 813, UK) was used to calculate the weight of each participant. Subjects stood barefoot wearing sports shorts. Duplicate readings were taken, and if measurements varied by 0.1 kg, a third measure was taken, and the median was recorded.
The maturity offset and age at PHV of the subjects was calculated using the following formula [23]: Maturity offset = −9.236 + 0.0002708 (leg length × sitting height) − 0.001663 (age × leg length) + 0.007216 (age × sitting height) + 0.02292 (weight-by-height ratio), where \( R = 0.94, R^2 = 0.891 \) and \( \text{SEE} = 0.592 \), and for leg length, standing height (cm) − sitting height (cm) was used. Afterward, the following formula was used to obtain PHV: age (years) − maturity offset (years).

2.6. Change of Direction Ability Test

Soccer players performed a “modified 505” [31] after warm-up, and they rested for 3 to 5 min to recover. One pair of the electronic timing system sensors (Newtest Oy, Finland) mounted on tripods was set at hip height and was positioned 3 m apart facing each other on either side of the starting line. The path was divided by three separate lines, A, B and C (line A: start; line B: 5 m after A; line C: 5 m after B). The front foot was placed 0.7 m on either side of the starting line. The path was divided by three separate lines, A, B and C (line A: start; line B: 5 m after A; line C: 5 m after B). The front foot was placed 0.7 m before line “A”. Each time, they had to touch the end of the straight path (line C) with at least one foot without touching the ground with a hand, then change direction as quickly as possible and return to the starting point (Figure 1). Between two trials, recovery was 3 min. The best time was recorded for analysis.

![Figure 1. How and where to perform test 505 on grass.](image)

2.7. Monitoring Workloads Training

The rating of perceived exertion (RPE) is one of the most usual affordable methods. This method is used to monitor internal training load, which provides valid information about the physiological influence of training [29].

The RPE was recorded using the CR-10 Borg’s scale [32]. This scale is reliable and has been validated to estimate the intensity of a session. Thirty minutes after the end of the training session, each player reported his RPE for each session confidentially without knowledge of other players’ ratings. As a measure of internal load, the session-RPE was derived by multiplying RPE and session duration (min) [33]. Players were previously familiarized with the scale during two years at the club.

On the other hand, different workload (WL) parameters were calculated. Weekly AWL was considered as a total load of daily training during the week; specific formulas [34] were used to obtain the weekly chronic (CWL) and chronic workload ratio (ACWLR), the weekly training monotony (TM) (weekly average AWL ÷ standard deviation (SD) of this week’s AWL) and, eventually, the weekly training statin (TS) (weekly AWL ×
weekly TM). These 15 weeks of the full competitive season were divided into two periods: early-season = W1 to W8 and end-season = W9 to W15 (Figure 2).

![Stages of assessed](image)

**Figure 2.** Timeline about monitoring during training, matches and assessed sessions during the competition season. Note: EaS, early-season; EnS, end-season, W, week; TS, training session.

### 2.8. Statistical Analysis

To analyze the general characteristics of study participants, the mean and standard deviation were estimated for all variables. The normality of the data was checked by a Shapiro–Wilk test. The association between the WL parameters and PHV was analyzed through a Person’s and Spearman’s correlation coefficient. The following amplitude of correlation levels was used [35]: <0.1 = trivial; 0.1–0.3 = small; >0.3–0.5 = moderate; >0.5–0.7 = large; >0.7–0.9 = very large and >0.9 = nearly perfect. Dependent t-tests with a 95% confidence interval (CI) were used to compare early-season vs. end-season once variables were obtained from the normal distribution. Non-parametric analyses were used to calculate differences within (Wilcoxon test) the early-season and end-season. The effect size was calculated using Cohen’s d, with values of 0.2, 0.6, 1.2 and 2.0 used to represent small, moderate, large and very large differences, respectively [36]. A multiple linear regression analysis between the percentage of reports of the COD ability, with variations in workload parameters and maturity variables, was performed. The Akaike information criterion (AIC) for each model’s regression was additionally calculated to support inferences about the model’s suitability. SPSS (version, 25.0; IBM SPSS Inc.; Chicago, IL, USA) was used for all statistical analyses, except for the multiple linear regression and AIC, which were calculated using Graph-Pad Prism 9 (GraphPad Software Ind., San Diego, CA, USA), with the level of significance set to p < 0.05.

### 3. Results

Table 1 shows Pearson’s and Spearman’s r correlations between the workload parameters and the COD ability test. Results indicated that COD early-season (r = 0.93; p ≤ 0.01) and TM early-season (r = 0.53; p ≤ 0.05) were nearly perfectly and moderately related to COD end-season. Likewise, AWL early-season was moderately and largely associated with TM early-season (r = 0.47; p ≤ 0.01), TS early-season (r = 0.49; p ≤ 0.01) and ACWL early-season (r = −0.59; p ≤ 0.01). In addition, CWL early-season was moderately and largely related to TM early-season (r = 0.32; p ≤ 0.01), TS early-season (r = 0.41; p ≤ 0.01) and ACWL early-season (r = −0.53; p ≤ 0.01). There were moderate associations between AWL early-season and COD end-season (r = 0.47; p ≤ 0.05). Furthermore, CWL early-season was moderately and largely related to ACWL end-season (r = 0.47; p ≤ 0.01) and TS end-season (r = 0.55; p ≤ 0.01), respectively. There were large correlations between AWL end-season and ACWL end-season (r = 0.71; p ≤ 0.01). Finally, TM early-season was nearly perfectly related to TS early-season (r = 0.93; p ≤ 0.01).
Table 1. Pearson and Spearman correlation analysis between the workload parameters and COD ability test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>β0</th>
<th>β1</th>
<th>β2</th>
<th>β3</th>
<th>β4</th>
<th>β5</th>
<th>β6</th>
<th>β7</th>
<th>β8</th>
<th>β9</th>
<th>β10</th>
<th>β11</th>
<th>β12</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHV (years) (β0)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>COD1 (s) (β1)</td>
<td>−0.21</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD2 (s) (β2)</td>
<td>−0.17</td>
<td>0.93 **</td>
<td>1</td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>AWL1 (A.U.) (β3)</td>
<td>0.03</td>
<td>0.35</td>
<td>0.47 *</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>AWL2 (A.U.) (β4)</td>
<td>−0.06</td>
<td>0.19</td>
<td>0.13</td>
<td>0.01</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CWL1 (A.U.) (β5)</td>
<td>0.05</td>
<td>−0.13</td>
<td>−0.21</td>
<td>0.19</td>
<td>0.08</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CWL2 (A.U.) (β6)</td>
<td>0.12</td>
<td>0.01</td>
<td>−0.19</td>
<td>−0.08</td>
<td>−0.06</td>
<td>−0.09</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACWL1 (A.U.) (β7)</td>
<td>−0.03</td>
<td>−0.35</td>
<td>0.42</td>
<td>−0.59 **</td>
<td>−0.07</td>
<td>−0.53 **</td>
<td>−0.07</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACWL2 (A.U.) (β8)</td>
<td>−0.06</td>
<td>0.22</td>
<td>0.03</td>
<td>0.02</td>
<td>0.70 **</td>
<td>0.13</td>
<td>0.47 **</td>
<td>−0.10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM1 (A.U.) (β9)</td>
<td>−0.08</td>
<td>0.53 *</td>
<td>0.06</td>
<td>0.47 **</td>
<td>−0.03</td>
<td>0.32 **</td>
<td>0.01</td>
<td>−0.32</td>
<td>0.03</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM2 (A.U.) (β10)</td>
<td>0.06</td>
<td>−0.09</td>
<td>0.01</td>
<td>0.09</td>
<td>0.04</td>
<td>0.15</td>
<td>−0.08</td>
<td>−0.10</td>
<td>−0.03</td>
<td>−0.08</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS1 (A.U.) (β11)</td>
<td>−0.19</td>
<td>0.38</td>
<td>0.33</td>
<td>0.49 **</td>
<td>0.01</td>
<td>0.41 **</td>
<td>−0.04</td>
<td>−0.38</td>
<td>0.09</td>
<td>0.93 **</td>
<td>−0.05</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>TS2 (A.U.) (β12)</td>
<td>−0.01</td>
<td>0.14</td>
<td>−0.16</td>
<td>0.06</td>
<td>0.20</td>
<td>−0.15</td>
<td>0.55 **</td>
<td>−0.15</td>
<td>0.13</td>
<td>0.08</td>
<td>0.01</td>
<td>0.12</td>
<td>1</td>
</tr>
</tbody>
</table>

PHV = peak height velocity; AWL = the accumulated acute workload in the season; CWL = the accumulated chronic workload in the season; ACWL = the accumulated acute:chronic workload ratio in the season; TM = the accumulated training monotony in the season; TS = the accumulated training strain in the season; (1): early-season; (2): end-season; * Significant difference ($p < 0.05$); ** Significant difference ($p < 0.01$). The descriptive workload and COD ability results and comparison between the early-season and end-season are presented in Table 2. Regarding data, there were significant differences between the early-season and end-season ($p \leq 0.05$; ES: $-0.16$ to $-1.21$) in all variables, except to TS ($p > 0.05$; ES: $-0.25$).
Table 2. Comparison of the early-season and end-season in the workload parameters and COD ability test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Early-Season (Mean ± SD)</th>
<th>End-Season (Mean ± SD)</th>
<th>p</th>
<th>Confidence Interval (95%)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD ability (%)</td>
<td>2.92 ± 0.32</td>
<td>2.88 ± 0.33</td>
<td>0.01 *</td>
<td>0.01, 0.06</td>
<td>−0.16 (−0.25; −0.07) (Trivial)</td>
</tr>
<tr>
<td>AWL (A.U.)</td>
<td>1442.5 ± 958.1</td>
<td>934.5 ± 157.7</td>
<td>&lt;0.01 *</td>
<td>148.9, 342.0</td>
<td>−0.65 (−0.86; −0.44) (Moderate)</td>
</tr>
<tr>
<td>CWL (A.U.)</td>
<td>1429.1 ± 110.4</td>
<td>1315.7 ± 27.8</td>
<td>&lt;0.01 *</td>
<td>162.7, 290.6</td>
<td>−1.17 (−1.47; −0.87) (Moderate)</td>
</tr>
<tr>
<td>ACWL (A.U.)</td>
<td>1.27 ± 0.05</td>
<td>0.64 ± 0.07</td>
<td>0.03 *</td>
<td>0.01, 0.22</td>
<td>−0.62 (−0.96; −0.28) (Moderate)</td>
</tr>
<tr>
<td>TM (A.U.)</td>
<td>1.49 ± 0.72</td>
<td>0.94 ± 0.49</td>
<td>&lt;0.01 *</td>
<td>0.19, 0.40</td>
<td>−1.21 (−1.52; −0.91) (Large)</td>
</tr>
<tr>
<td>TS (A.U.)</td>
<td>2592.1 ± 2270.4</td>
<td>1840.2 ± 1442.7</td>
<td>0.22</td>
<td>−98.2, 413.36</td>
<td>−0.25 (−0.46; −0.04) (Small)</td>
</tr>
</tbody>
</table>

AWL = the accumulated acute workload in the season; CWL = the accumulated chronic workload in the season; ACWLR = the accumulated acute:chronic workload ratio in the season; TM = the accumulated training monotony in the season; TS = the accumulated training strain in the season. * Significant difference (p < 0.05).

Multiple linear regression analyses were performed to predict the percentage of change in COD ability based on workload and maturity (Table 3 and Figure 3). The analysis of COD ability showed that they were significant (F(5, 13) = 3.22, p = 0.04), with a R² of 0.55. Participants showed good predictions for COD ability; (Y) was equal to Beta0 + Beta1 (AWL) + Beta2 (CWL) + Beta3 (TM) + Beta4 (TS) + Beta5 (PHV), where workload parameters were measured as A.U., and PHV was measured as years in an order based on the equation.

Table 3. Multiple linear regression analysis: percentage of change in COD ability with workload and maturity.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Beta</th>
<th>Estimate</th>
<th>t</th>
<th>p Value</th>
<th>95% CI for Estimated</th>
<th>Total Predict</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD ability (%)</td>
<td>β0</td>
<td>5.74</td>
<td>0.99</td>
<td>0.33</td>
<td>−6.70, 18.2</td>
<td></td>
</tr>
<tr>
<td>AWL (A.U.)</td>
<td>β1</td>
<td>0.01</td>
<td>2.19</td>
<td>0.04 *</td>
<td>0.01, 0.01</td>
<td>R²: 0.55</td>
</tr>
<tr>
<td>CWL (A.U.)</td>
<td>β2</td>
<td>−0.01</td>
<td>1.61</td>
<td>0.13</td>
<td>−0.01, 0.01</td>
<td>Estimated R²: 0.38</td>
</tr>
<tr>
<td>TM (A.U.)</td>
<td>β3</td>
<td>0.07</td>
<td>0.18</td>
<td>0.85</td>
<td>−0.76, 0.91</td>
<td>p: 0.04</td>
</tr>
<tr>
<td>TS (A.U.)</td>
<td>β4</td>
<td>−0.00</td>
<td>0.69</td>
<td>0.49</td>
<td>−0.01, 0.01</td>
<td>AIC value: 32.44</td>
</tr>
<tr>
<td>PHV (years)</td>
<td>β5</td>
<td>0.72</td>
<td>1.32</td>
<td>0.21</td>
<td>−0.46, 1.91</td>
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AWL = the accumulated acute workload in the season; CWL = the accumulated chronic workload in the season; ACWLR = the accumulated acute:chronic workload ratio in the season; TM = the accumulated training monotony in the season; TS = the accumulated training strain in the season; PHV = peak height velocity; COD = change of direction; % = the percentage of change in between assessments from early-season to after-season; AIC: Akaike information criterion, and CI = confidence interval; * Significant difference (p < 0.05).

Figure 3. A multiple linear regression analysis was conducted to predict the percentage of change in fitness levels. (a) COD based on accumulated workloads, and PHV in the soccer players. Furthermore, (b) a residual plot was calculated to predict the percentage of change in COD levels, the difference between the actual value of the dependent variable and the value predicted by the residual provided. Note: COD = Change of direction; PHV = Peak height velocity.
4. Discussion

The present study analyzed the relationship between the variations of accumulated workload and COD performance in elite youth soccer players. The main findings revealed that there is a correlation between workload parameters and the COD ability test. Another interesting result from our study is that the youth soccer players showed good predictions for COD ability. The control of workload and, in particular, the accumulated workload are variables of great interest in exercise prescription and its relationship with anaerobic power. Furthermore, there seems to be a relationship between the control of the external load and variations in the body composition, isokinetic strength and aerobic capacity of professional soccer players [9].

The main purpose of load control is to understand the impact of the different workouts that are present in the training session on measures such as heart rate, blood lactate and oxygen consumption. The RPE scales are commonly used to assess internal load. In contrast, external training loads are objective measures of the work performed by the athlete during training or competition and are evaluated independently of internal workloads. Common external load measurements include power output, speed, acceleration, time-motion analysis, global positioning system parameters and accelerometer-derived parameters [37]. In addition, quantifying the load and controlling it is fundamental to identify the magnitude of different physical skills during training [38], and one of the ways to control the internal load is the use of the RPE (it has large advantages relative to evaluating the internal training load [39]), which was used in this intervention.

We found a significant correlation between COD end-season and AWL early-season. We observed that there was a significant reduction in COD ability towards the end of the season. One potential reason for the decrease in COD ability towards the end of the season could be due to the higher AWL during the early-season compared to the end-season (1442.5 vs. 934.5). In a previous study by Nobari et al. [40], the AWL was reported to be higher during the start of the season compared to the end of the season in youth soccer players (under-14). The higher load during the beginning of the season could be to prepare the players for the intensity of the upcoming season [41]. The COD early-season performance was significantly correlated with TM early-season. The TM was developed by Foster (1998) [33] in order to measure the fluctuation in the daily training load in a week. The TM in this study was found to be higher during the early-season (1.94) compared to the end-season (0.94). A monotony index of greater than 2 A.U has been associated with an increased risk for illness and overtraining in athletes [33]. Therefore, it can be said that the TM values within our study were within the prescribed values. It is prudent to assume that the adequate values of monotony are related to optimal load variation. Furthermore, it is also essential to maintain an appropriate increase in performance and reduction of injury risk as well. However, it is difficult to compare our results with the previous published studies in the existing literature due to the limited information available on youth soccer players, warranting further research.

A non-significant correlation was observed between ACWLR and COD ability in our study. However, the ACWLR during the early-season was found to be higher than at the end of season. This could be explained by the low chronic TL, which was observed during the early part of the season [42]. Since a higher acute TL relative to a chronic TL has been reported to induce positive training adaptations, this could explain the better COD performance during the early-season [43]. Generally, an ACWLR value below 1.5 has been recommended in order to maintain a safe increase of the training WL [44] and reduce the risk of injuries, although this value depends upon the sport, athletes, period of the season and other variables [37]. However, there is still some controversy regarding the use of ACWLR in predicting injuries, with studies by Fanchini et al. [45] and Impellizzeri et al. [46] reporting that this method has no scientific merit to predict the injury risk and rate of athletes. However, ACWLR can still be used to monitor changes in fitness levels of players [47] and to determine the optimal weekly load division to ensure a sufficient post-match recovery and prevent pre-match fatigue [48].
Our findings revealed that a non-significant correlation exists between COD performance and the PHV. The PHV assessment is a minimally invasive, feasible, practical indicator of somatic maturation and is associated with stronger, faster and taller athletes [49]. The PHV method cannot be used in cross-sectional studies in which only a single measurement is possible, due to the fact that several measures are necessary to measure the PHV during the growth period [50]. The method used to measure the PHV in our study has been found to have good reliability ($r^2 = 0.89$) and a low standard error of estimation (SEE = 0.569) [51]. Previous studies have reported that a strong relationship exists between biological maturation and performance, with the potential reasons being the development of biological systems, such as cardiorespiratory and muscular systems [52]. For instance, a study by Philippaerts et al. (2005) evaluated balance, speed of limb movement, trunk strength, upper-body muscular endurance, explosive strength, running speed and COD, cardiorespiratory endurance and anaerobic capacity and reported that the peak development occurred at the PHV [53]. The interaction between genes, hormones, nutrients and environmental factors have been found to trigger a chain of physical and functional alterations in the body during adolescence years [54]. Physical performance is highly influenced by maturation [55], and the optimal period for improving physical, technical and physiological capacities is between 12 and 16 years of age. Early maturing players have been shown to have greater stature, body mass, muscular strength and aerobic fitness [56,57]. The lack of correlation between the PHV and COD performance in the current study could be due to the in-between comparison of soccer players belonging to the same age group [58]. The similar training ages of the participants in our study may have offset any potential benefits of advanced maturity status on COD performance [58]. However, further research is required to confirm these findings and help us in better understanding this topic.

The regression model showed that COD performance can be predicted using the training load parameters and the PHV. Physical maturity has been reported to influence football-related physical characteristics performance [59–61]. Previous studies by Parr et al. (2020) and King et al. (2021) have also reported that maturation status can be used as a significant and positive predictor for performance during COD tasks in youth soccer players [62,63]. These changes in performance could be attributed to the combined changes in the anatomical structure, size, metabolism and neuromuscular system [61]. The training load parameters also contributed to predicting COD performance during the early-season and end-season. Load monitoring variables, such as AWL, CWL, TM and ACWR, can be used as robust tools for predicting injuries, as they take into consideration the accumulation and variability in training load over time [33,64,65]. A previous study by Clemente et al. reported that the accumulated weekly training WL has a high correlation with various performance parameters in soccer players. This finding can be associated with higher loads that can be employed during the workouts due to the improvement in physical abilities following the PHV [66,67].

Our study has some limitations. Firstly, the small sample size and the inclusion of only one team for analysis are the two main limitations of our study. Future studies should include more than one team in order to give more scientific support to the results and conclusions. Secondly, COD ability was measured only during the start and end of the season. It would be useful to get measures throughout the season in order to get a better understanding of how TL variables influence COD performance. The next limitation of the present study was the lack of external load monitoring for the evaluation of total distance, accelerations and decelerations, average maximal and mean velocity and other variables [68,69]. These are recommended to be monitored and analyzed in future studies. Finally, our study did not compare and contrast how COD performance might vary in response to training during a season across youth soccer players of various ages (under-12, under-15, under-16). Such information could be useful for practitioners in tailoring workout plans and planning the workload specific to each age group.
The findings from our study have a few practical applications. TL management using tools such as sRPE would make it possible to propose optimal load values and modulate the players’ performance during training. This information can be useful in identifying individual youth soccer players who are at a higher risk of injury and also in designing and implementing recovery protocols after training sessions or matches. Furthermore, the TL and PHV can be used as predictors of COD performance. Therefore, coaches and practitioners can use this information for talent identification and in implementing training routines and workouts, taking this information into consideration in order to help the players transition through to a higher playing level.

5. Conclusions

The current research revealed the associations between workload parameters and maturation and determining performance during COD tasks in youth soccer players. Significant correlations were observed between the COD end-season and AWL early-season and the COD early-season and TM early-season. The decrease in the COD ability at the end of the season could have been due to the higher AWL during the early-season. The TM was higher at the start (1.94) than at the end of the competitive season (0.94). Adequate values of monotony (<2.0 A.U.) are necessary to reduce injury risk and increase performance. Nevertheless, a non-significant correlation exists between COD performance and the PHV. The reason could be due to the in-between comparison of soccer players belonging to the same age group. AWL, CWL, TM, TS and PHV were found to be significant predictors of COD performance in under-16 soccer players. These variables could be interesting tools for predicting overtraining and injuries. The findings should provide useful information to coaches and practitioners for developing training programs aimed at developing the COD ability based on training load and the PHV in youth soccer players.


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