



Aerobic Fitness of Starter and Non-Starter Soccer Players in the Champion's League

by

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To identify individual response patterns in selected aerobic fitness variables of regular starters (ST; N = 7) and non-starters (Non-ST; N = 10), top level professional soccer players were tested for maximal oxygen uptake (VO_{2max}), velocity at 4 mM of lactate (V_4), velocity at maximal oxygen uptake (vVO_{2max}) and oxygen pulse (O_2 -pulse) in July and December following consecutive periods of fixture congestion. V_4 was the only variable that increased significantly in December compared to July (15.1 ± 0.5 vs. 14.6 ± 0.5 , $p = 0.001$). There was an almost certain beneficial large mean team change for V_4 (ES = 1.2 (0.67; 1.57), 100/0/0), while beneficial mean team changes were less likely for vVO_{2max} and O_2 -pulse [ES = 0.31 (-0.08; 0.70), 68/30/2 and ES = 0.24 (0.01; 0.49), 64/36/0, respectively] and unclear for VO_{2max} (ES = 0.02 (-0.31; 0.70), 18/69/13). With the exception of V_4 where 10 out of 17 players (7 ST and 3 Non-ST) showed positive changes higher than the biological variability, all other variables were characterized by a substantial proportion of changes lower than the biological variability. The present study demonstrated that aerobic fitness variables that require maximal effort may be characterized by greater variability of the individual response pattern compared to that of submaximal aerobic fitness variables irrespective of the accumulated game time. Submaximal aerobic fitness variables appear to be more informative in the physiological evaluation of top level soccer players and this may be an advantage during exposure to periods of consecutive games.

Key words: magnitude-based inferences, smallest worthwhile change, biological variability, fixture congestion, submaximal endurance.

Introduction

Aerobic fitness is an important physical variable to consider in top-level soccer since elite players cover 10-12 km during a competitive match at an average intensity of ~70% of their maximal oxygen uptake (VO_{2max}) (Bangsbo et al., 2006; Stolen et al., 2005). Both descriptive and training studies have shown a relationship between various markers of aerobic fitness and competitive ranking or team level (Helgerud et al., 2001; Hoff and Helgerud 2004; Impellizzeri et al., 2006; Mohr et al., 2002). In addition, these markers of aerobic fitness have demonstrated ecological validity in professional soccer (Castagna et al., 2011, 2013) and sensitivity to training load variations as well as to both pre- and

in-season general conditioning and soccer specific training interventions (Castagna et al., 2011; Impellizzeri et al., 2006). For these reasons repeated testing as well as consistent training are important for the monitoring, maintenance and further development of aerobic fitness (Castagna et al., 2011, 2013; McMillan et al., 2005).

Soccer players competing at top-level are usually required to participate in weekly matches of their national league as well as in international competitions. In certain circumstances exposure to official international games starts as early as in the first weeks of July (i.e. qualifying rounds for major international competitions such as the UEFA Champions League or UEFA Europa

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League). During the official in-season domestic league, matches at the weekend are usually split by a midweek European match (Dupont et al., 2010; Odetoynbo et al., 2007) and this can create consecutive periods of fixture congestion (Djaoui et al., 2014). In such cases teams may need to rely upon a shortened pre-season period (≤ 6 weeks) and thus, the main focus during the in-season might be to maintain pre-season aerobic fitness improvements for as long as possible (Turner and Stewart, 2014).

The consecutive in-season competitive demands impose strains mainly to musculoskeletal, nervous, immune and metabolic systems (Ascensao et al., 2008; Bangsbo et al., 2006; Brites et al., 1999; Kraemer et al., 2004). Balancing between physical training and tapering/recovery strategies for alleviating match-related fatigue and restoring bodily systems becomes pivotal in the maintenance of adequate aerobic fitness levels (Chad, 2010). In fact in-season fixture congestion is a major concern for physical trainers since the reduced opportunities for physical training may progressively lead to aerobic fitness deterioration in the long term (Chad, 2010; Gamble, 2006).

One variable that may however differentiate the effect of reduced in-season physical training on long term aerobic fitness levels is the dose of playing-time since even in periods with increased competitive demands some players may accumulate more game time compared to others due to technical or tactical reasons. In fact, it has been proposed that game time may aid in the maintenance or even contribute to an increase of aerobic fitness in professional soccer players (Silva et al., 2011; Sporis et al., 2011). However, it is currently unknown if "too much" game time may actually have detrimental effects on physical fitness. This issue is further complicated since players are individuals with different capabilities, different match loads and potentially different recovery requirements; therefore, accumulated game time per se may not be an important determinant of aerobic fitness changes (Sporis et al., 2011).

Consequently, the aim of the present study was to identify individual response patterns (as opposed to mean changes) in selected fitness variables in a sample of regular starters and non-starters of a professional soccer team participating

in the UEFA Champions League following consecutive periods of fixture congestion. To quantify individual responses, improvements and negative changes larger than the biological variability of each one of the dependent variables were defined as a meaningful response (Hopkins et al., 2009; Scharhag-Rosenberger et al., 2012). Changes (either positive or negative) not more than the biological variability of the respective variable were defined as a non-response (Scharhag-Rosenberger et al., 2012). This represents a novel approach to evaluate endurance changes on an individual basis.

Methods

Participants

A group of 26 male professional outfield players was initially involved in the protocol. As a result of injuries and transfers/loans to other clubs, 9 players were not considered in the analysis, thus the final sample comprised 17 outfield players (age: 29.5 ± 4.0 years; body height: 1.80 ± 0.05 m; body mass: 76.0 ± 6.2 kg). The final sample consisted of 7 domestic and 10 foreign players. Six of the domestic players participated in the national team and the 1 in the U-21 national team. Seven of the foreign players were EU nationals and 3 Non-EU nationals. One of the Non-EU nationals participated in his national team. All players had at least 3 years of experience at professional level soccer. Players had to be free from injury during the previous 4 weeks before a testing session. As part of their pre-participation health screening all soccer players underwent standard medical evaluation at the beginning of the season (physical examination, blood sample analyses, rest electrocardiogram, lung x-ray). All players were familiar with the experimental procedures, and aware of discomforts and possible risks of the present study, since they had participated in a similar type of testing in the past. Subjects were informed about the experimental procedures and signed a written informed consent form. The experimental protocol complied with the Declaration of Helsinki for research with human subjects. Ethical approval was granted by the University of Nicosia Ethics Committee. The players' total time spent in official games was recorded throughout the season. At the end of the season, players that had accumulated $\geq 60\%$ of the total official game time

were regarded as starters (ST). Non-starters (Non-ST) accumulated $\leq 40\%$ of the total official game time. Players were blinded to the aims of this study (Castagna et al., 2011).

Yearly playing schedule

The pre-season period started in the 1st week of June when also the 1st physiological testing took place. Due to the teams' participation in the 2nd round of the UEFA Champions League qualifying phase, the first two official games of the season took place in the 2nd week of July. The team continued with another two games for the 3rd round of the UEFA Champions League qualifying phase that were held in the last week of July and 1st week of August and two games for the UEFA Champions League play-off round that were held in 3rd week of August. The 1st official game of the national league took place in the last week of August and the 1st official game of the UEFA Champions League group-phase was in the last week of September. During the season the team played 26 championship games, 3 cup games, 6 championship play-off games and 10 UEFA Champions League games. The second test took place in the last week of December approximately 7 days after an official match (first match of the championship second round). There were three periods of congested fixture schedule before the second physiological testing. The 1st period was located between the 2nd week of September and 1st week of October with 6 matches (4 championship and 2 CL) in 24 days. The 2nd was located between the 3rd week of October and 1st week of November with 6 matches (4 championship and 2 CL) in 23 days. Finally the 3rd congested period was located between the 3rd week of November and 2nd week of December with 6 matches (4 championship and 2 CL) in 23 days. These congested periods involved microcycles with 2 games/week alternated with periods of international truce and standard microcycles with 1 game/week. All players included in the analysis performed 6-7 training sessions during 1 game/week microcycles and 5 sessions during 2 games/week microcycles. These sessions also included recovery strategies when appropriate, such as massages, consumption of prescribed recovery-drinks and dietary supplements, and alternating cold and hot water immersion of the legs. Recovery strategies were performed on the days after the games and were

held consistent during the whole season.

Measures

The coaching staff decided that testing should be completed within 1 day and should be focused on the players' physiological profile. It was further decided that fitness testing should be minimized and thus testing following the conclusion of the pre-season period was omitted. Limited by these restrictions, the following variables were selected: VO_{2max} , velocity at a fixed lactate concentration of 4 mM (V_4), velocity at maximal oxygen uptake (vVO_{2max}) and oxygen pulse (O_2 -pulse). These variables represent different combinations of cardiorespiratory, muscle/metabolic and neuromuscular adaptations at both maximal and submaximal level (Billat and Koralsztein, 1996; Billat et al., 1999; Whipp et al., 1996) and have been extensively studied in top level soccer players (Castagna et al., 2011, 2013; Kalapotharakos et al., 2011; McMillan et al., 2005; Stolen et al., 2005).

Subjects reported to the laboratory fully hydrated and having avoided caffeine consumption for 4 hours. They had been given instructions to follow a standard diet the day before testing and eat a high carbohydrate light meal (60% carbohydrates, 300-400 kcal) 4 hours before testing. The coaching staff had not scheduled intense training sessions for 48 hours before each of the two testing sessions. Body height and mass were measured using a calibrated stadiometer and scale (Seca, Hamburg, Germany), respectively. During a warm-up, the subjects performed 5 minutes of jogging on a treadmill (Technogym Runrace 1200, Gambettola, Italy). Subsequently, subjects performed an incremental exercise test to volitional exhaustion with expired gas and heart rate analysis using a computerized system (CPX Ultima, Medical Graphics, St. Maul, MN, USA). The heart rate was measured throughout the test using a Polar heart rate monitor (Polar Corporation, Finland). The initial speed of the incremental test was set at 10 $km \cdot h^{-1}$ and was increased by 2 $km \cdot h^{-1}$ every 3 min until volitional exhaustion (Billat and Koralsztein, 1996). At the end of each 3 min stage capillary blood samples were collected and analyzed for lactate using an automated analyzer (Accutrend, Roche Diagnostics, Mannheim, Germany). Criteria for VO_{2max} attainment were a) plateau in VO_2 (an increase less than 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ despite

an increase in running speed), b) respiratory exchange ratio (RER) greater than 1.10, (c) HR $\pm 2.5\%$ of the age predicted maximal heart rate (HR_{max}), and (d) maximal blood lactate after exercise greater than 8 mM. Blood-lactate concentrations were plotted against running speeds and HR elevation, and individual blood-lactate concentration profiles (V_4) were identified via linear extrapolation (McMillan et al., 2005). vVO_{2max} was calculated as the minimum speed at which the soccer player ran when VO_{2max} occurred, as long as this speed was sustained for at least 1 minute (Billat et al., 1999). O_2 -pulse was calculated as the ratio of VO_{2max}/HR_{max} (Whipp et al., 1996).

Statistical analysis

Data in text and figures are presented as mean \pm SD. The distribution of each variable was examined with the Kolmogorov-Smirnov normality test. Data were initially analyzed using a 2-factor repeated measures analysis of variance with 1 between factor (starters; ST vs. non-starters; non-ST) and 1 within factor (period; preseason vs. middle of the in-season). These analyses were carried out with Statistica Software (Statistica v10.0, Statsoft Inc, USA), and the level of significance was set at $p \leq 0.05$. In addition to this null hypothesis testing, the data were also analysed for practical significance using a magnitude-based approach (Hopkins et al., 2009). The standardized difference or effect size (ES) of changes in each fitness variable was calculated using the pooled standard deviation (Hopkins et al., 2009). Threshold values for Cohen ES statistics were >0.2 (small), >0.5 (moderate), and >0.8 (large) (Castagna et al., 2011, 2013). For the within comparisons, the chance that the true (unknown) value for each variable was *beneficial/better* [greater than the smallest practically important effect or the smallest worthwhile change (0.2 multiplied by the between-subject standard deviation, based on Cohen ES principle)] (Cohen, 1988), *trivial* or *detrimental/worse* for performance was calculated. Quantitative chances of *beneficial/better* or *detrimental/poorer* effect were assessed qualitatively as follows: $<1\%$, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; and $>99\%$, almost certain. If the chance of having *beneficial/better* or *detrimental/poorer* performances was both $>5\%$, the

true difference was deemed *unclear* (Hopkins et al., 2009). To assess the individual responses and the respective changes in performance between the pre-season and the middle of the in-season, the selected physiological variables were examined using a publicly available spreadsheet (Hopkins, 2003). Variables were log-transformed for all analyses to reduce bias due to non-uniformity of error, back-transformed and expressed as a percentage (Hopkins et al., 2009). As a measure of day-to-day variability, within-subject coefficients of variation (CVs) of the four variables were extracted from the literature. They were 5.6% for VO_{2max} and 1.9% for V_4 (Scharhag-Rosenberger et al., 2012). We were not able to retrieve a reliability study for calculating CV for vVO_{2max} and O_2 -pulse. Subsequently, CVs for these two variables were calculated from a publicly available spreadsheet and were 3.2% and 3.7% for vVO_{2max} and O_2 -pulse, respectively (Hopkins, 2003). Individual pre-post positive differences of more than one CV were considered as improvements, whereas negative changes of more than one CV were considered as deteriorations; changes (either positive or negative) smaller than one CV were defined as a non-response (Scharhag-Rosenberger et al., 2012).

Results

Results for the between-groups comparisons of the selected variables are presented in Table 1. There was a statistically significant main effect of time for V_4 . V_4 in December was significantly higher compared to V_4 in June (15.1 ± 0.5 vs. 14.6 ± 0.5 , $p = 0.001$). O_2 -pulse in December tended to be higher compared to O_2 -pulse in June, but the difference did not reach statistical significance (22.6 ± 2.7 vs. 22.0 ± 2.0 , $p = 0.08$). There was no other significant main effect or interaction for any of the tested physiological variables.

Results for practical significance are presented in Table 2. There was an almost certain large mean team improvement for V_4 (ES = 1.2 (0.67; 1.57), 100/0/0), possibly small mean team improvements for vVO_{2max} and O_2 -pulse [ES = 0.31 (-0.08; 0.70), 68/30/2 and ES = 0.24 (0.01; 0.49), 64/36/0, respectively], and unclear mean team changes for VO_{2max} (ES = 0.02 (-0.31; 0.70), 18/69/13).

Results of the individual responses for the

tested variables are presented in Figure 1. With the exception of the individual responses for V_4 where 10 out of 17 players (3 ST and 7 Non-ST) had an increase larger than the biological variability, all other variables demonstrated substantial non-response patterns. Specifically, 4 out of 7 ST and 8 out of 10 Non-ST had a non-response in VO_{2max} . Four out of 7 ST and 6 out of 10 Non-ST had a non-response in vVO_{2max} , while 2

out of 7 ST and 5 out of 10 Non-ST had a non-response in O_2 -pulse.

High variability characterized also the within-player response (Figure 2). Only 1 out of 17 players (1 Non-ST) had an increase in all tested variables. Only 2 out of 17 players (1 ST, 1 Non-ST) had an increase in 3 out of the 4 tested variables. Ten out of 17 players (5 ST, 5 Non-ST) had an increase in no more than one out of the 4 tested variables.

Table 1

Main effects and interactions for all tested physiological variables.

| | groups | | time | | time*groups | |
|--------------------------------|--------|-------|-------|--------|-------------|-------|
| | F | p | F | p | F | p |
| VO_{2max} | 0.977 | 0.339 | 0.001 | 0.980 | 0.105 | 0.751 |
| V_4 | 0.00 | 0.997 | 17.01 | 0.001* | 0.43 | 0.523 |
| vVO_{2max} | 0.001 | 0.976 | 1.35 | 0.263 | 2.661 | 0.124 |
| O_2-pulse | 0.419 | 0.527 | 3.46 | 0.08* | 0.05 | 0.876 |

Table 2

Changes in physical fitness between July and December. Mean group changes are quantified based on a clear decision (i.e., at least possible difference) together with a standardized difference ≥ 0.2

| | July mean (\pm SD) | December mean (\pm SD) | Cohen D (90% CI) | % chances of better/trivial/poorer | Qualitative outcome |
|--|--------------------------|------------------------------|-----------------------|---------------------------------------|------------------------------|
| VO_{2max} ($ml \cdot min^{-1} \cdot kg^{-1}$) | 54.5 (3.7) | 54.5 (3.2) | 0.02 (-0.31; 0.35) | 18/69/13 | unclear |
| vVO_{2max} ($km \cdot h^{-1}$) | 17.4 (0.8) | 17.7 (0.9) | 0.31 (-0.08; 0.70) | 68/30/2 | possibly small |
| V_4 ($km \cdot h^{-1}$) | 14.6 (0.5) | 15.1 (0.5) | 1.12 (0.67; 1.57) | 100/0/0 | almost certainly large |
| O_2 -pulse ($ml \cdot heart\ beat^{-1}$) | 22.0 (2.0) | 22.6 (2.8) | 0.25 (0.01; 0.49) | 64/36/0 | possibly small |

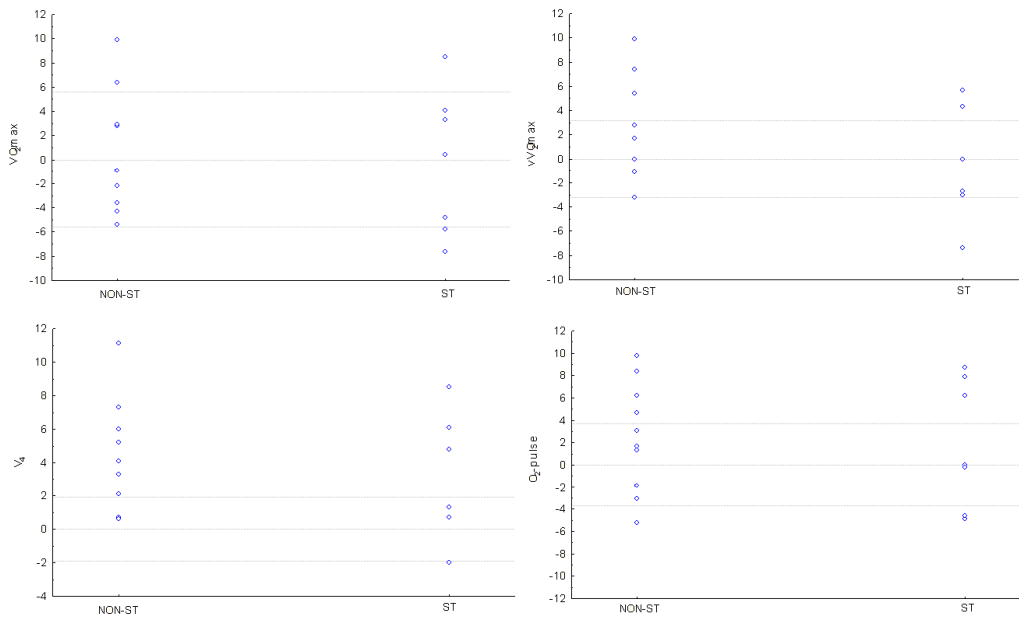


Figure 1

Scatterplots of individual responses for the tested variables in ST and Non-ST players. Horizontal lines represent boundaries for non-responses. See Methods for calculation of the magnitudes of changes.

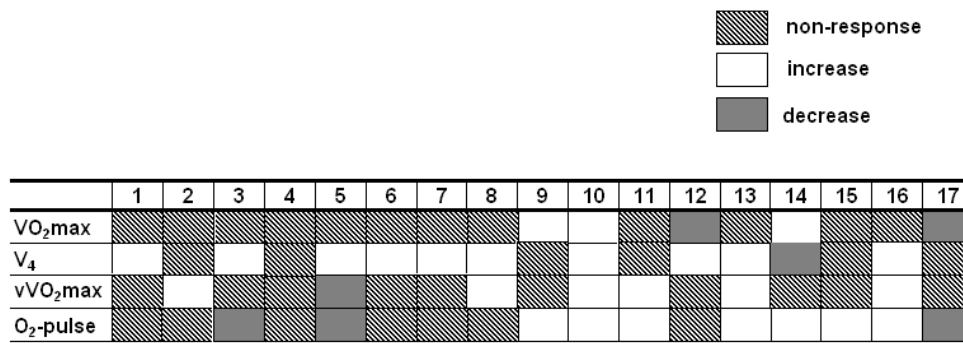


Figure 2

Individual physiological changes. Grey square, decrease (negative change>biological variability); white square, increase (positive change>biological variability); shaded square, non-response.

Discussion

The major finding of the present study was that with the exception of V4 that produced meaningful mean team increases from July to December, none of the other tested variables demonstrated clear (i.e. changes for beneficial mean team changes $\geq 75\%$) mean team responses in a group of professional soccer players of a team that participated in the UEFA Champions League. In addition, with the exception of V4 that demonstrated the most consistent pattern of individual positive changes, a substantial proportion of non-responses or even decreases, was evident for the rest of the tested variables irrespective of official game participation (ST vs. Non-ST). A non-response in at least one variable was evident for all but one player (16/17). Fifteen out of 17 players responded positively in at least one variable. Individual decreases were evident for all variables.

Regarding VO_{2max} our results showed no statistically significant change between July and December for both ST and Non-ST (Table 1). In addition when tested for practical significance results showed an unclear change (Table 2). Our results appear to contradict data from the literature that indicate significant mean improvements from the pre-season to the middle of the in-season (Kalapotharakos et al., 2011; Mohr et al., 2002). A possible explanation maybe revealed by the individual response pattern which indicated a substantial proportion of non-response for both ST and Non-ST. Furthermore, it seems that the magnitude of the negative changes in VO_{2max} may have been more pronounced for the ST since none of the Non-ST deteriorated their VO_{2max} and the only 2 individual negative changes were in fact ST (Figure 1). The fact that no individual negative change occurred for the Non-ST is in contrast with Sporis et al. (2012) who postulated that official game time may actually aid in the maintenance of physical fitness in professional soccer players. However, the small sample precludes from definite conclusions (Figure 2). VO_{2max} generally depends on the subjects' maximal effort during the exercise test and, therefore, the possibility of residual fatigue affecting effort levels has also to be considered (Meyer et al., 2005). In this regard, 8 out of 12 players that showed a non-response in VO_{2max} also failed to respond positively to the other

variables that required maximal effort (vVO_{2max} and O_2 -pulse), thus it is possible that a combination of residual fatigue/lower exertion during the test may have obscured the VO_{2max} values. Nevertheless, it should be pointed out that despite these variable responses, the mean group VO_{2max} value at the middle of the in-season was at the low end-range of mean VO_{2max} values for elite soccer players ($55-67 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$) (Hoff and Helgerud, 2004).

Regarding V4, the current results showed statistically significant mean team improvements between July and December for both ST and Non-ST (Table 1). In addition, testing for practical significance demonstrated an almost certain large mean team change (Table 1). These results support the existing literature showing significant improvements at various derivatives of the blood lactate-velocity relationship such as lactate threshold or fixed thresholds of 2, 3, and 4 mM (Kalapotharakos et al., 2011; McMillan et al., 2005). Furthermore, our analysis of the individual responses demonstrated a substantial proportion of positive adaptations (Figure 2). When considering the impact of accumulated playing time, 3/7 ST and 7/10 Non-ST had an improvement in V4 values. In addition a proportion of both ST and Non-ST showed a non-response (Figure 1). It would appear that the magnitude of positive adaptations may have been more pronounced for the Non-ST, but given the small sample it is not possible to draw safe conclusions. It should also be pointed out that V4 at baseline was not significantly different between ST and Non-ST (Table 1), thus any possibility of greater adaptations for the Non-ST may not be attributed to their lower initial values. Furthermore, our mean group V4 values in both July and December seem to be higher compared to adult sub-elite (Kalapotharakos et al., 2011) or youth elite (McMillan et al., 2005) soccer players. It has been demonstrated that the lactate threshold might change without changes in VO_{2max} (Helgerud et al., 2001). This was also verified by our individual responses where only 1/10 players that increased V4 had also a concurrent improvement in VO_{2max} . In addition a significant proportion of the non-responders in VO_{2max} demonstrated an increase in V4 and the only player that in fact decreased in terms of V4 did display an increase in VO_{2max} . The current

data appear to confirm findings of Edwards et al. (2003) who have suggested that the various derivatives of blood lactate thresholds are more sensitive indicators of training-induced changes in aerobic fitness than VO_{2max} .

The present data on vVO_{2max} demonstrated no statistically significant mean team change between July and December for both ST and Non-ST (Table 1). In addition, testing for practical significance demonstrated possible but not clear mean team improvement (chances for beneficial effect were <75%) (Hopkins et al., 2009). The individual responses showed that only 2/7 ST but 4/10 Non-ST were able to produce worthwhile positive adaptations (Figure 2), which may be of importance since baseline values did not differ (Table 1). However, due to the small sample we cannot make clear inferences. It has been proposed that vVO_{2max} combines VO_{2max} (maximal component) and running economy (submaximal component) into a single factor (Bangsbo et al., 2006). The current individual responses tend to indicate that vVO_{2max} improvements may have been based upon improvements in the submaximal component since 4/6 players showed concurrent submaximal aerobic fitness improvements (i.e. V4); in contrast, only 1/6 had concurrent improvements in VO_{2max} (Figure 2).

Regarding O_2 -pulse, we observed no statistically significant mean team change between July and December for both ST and Non-ST (Table 1). Testing for practical significance demonstrated possible but not clear mean team improvement (chances for beneficial effect were <75%) (Hopkins et al., 2009). O_2 -pulse followed similar individual patterns to VO_{2max} since a significant proportion of non-responders in VO_{2max} also showed a lack of improvement in O_2 -pulse (Figure 2).

The major limitation of the present study is the lack of testing following the completion of the pre-season period. However, due to the potential financial importance of the official games in early July, the coaching staff decided to prepare the team for a possible series of two-legged ties. Furthermore, another limitation is the small sample and the absence of data regarding

training loads during the study period. An additional limitation may be the lack of anaerobic performance evaluation (i.e. speed or power), which is an important component of peak soccer performance. However, evaluating these abilities would require additional days of testing. It was the decision of the coaching staff that testing should be devoted to physiological factors. Future studies should examine the seasonal aerobic performance variation in relation to both the training load and accumulated game time which adds further to the total player load (Chad, 2010). Furthermore, it should be acknowledged that the present study is a case study and as such represents the weakest form of scientific evidence. However, data regarding soccer teams participating in top level competitions such as the UEFA Champions League are scarce. The team had a successful campaign starting from the Champions League second qualifying round until the Champions League quarter-final. What is evident is that the physiological data presented were not exceptional (Hoff and Helgerud, 2004). This points to other components of fitness being of importance for long-term seasonal success, yet the role of technical and tactical elements should not be neglected.

In conclusion the present study demonstrated that despite the apparent stability in mean values for maximal aerobic fitness variables, there was high variability in the individual response pattern. On the contrary, a submaximal aerobic fitness variable, such as V4, showed high consistency in the individual response patterns for both ST and Non-ST players. It was shown in general that individual increases in V4 may occur without concurrent increases in VO_{2max} , vVO_{2max} , O_2 -pulse. In our setting, V4 was tested concurrently with maximal variables, however this variable can also be assessed using a submaximal test (McMillan et al., 2005). The relatively low level of imposed fatigue compared to maximal effort tests (VO_{2max} , YO-YO, vVO_{2max}) and the consistency of the individual responses make this variable important for monitoring seasonal aerobic fitness in professional soccer players.

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