AEROBIC TRAINING DOES NOT IMPROVE COMPETITIVE PERFORMANCE IN YOUNG ELITE BASKETBALL PLAYERS

Carlos Claramunt[1], Ivar Guzman[1], Joan Solé[1], Natàlia Balagué[1], Robert Hristovski[2]
University of Barcelona[1], Barcelona, Spain
University of Ss. Cyril and Methodius[2], Skopje, Macedonia

ABSTRACT

Research background and hypothesis. While for some authors team sport players should have a high VO_2max, we hypothesize that there exist a non-linear relationship between VO_2max and basketball performance.

Research aims. Research aims were to study the correlation between basketball performance and VO_2max in young elite basketball players and the effects of VO_2max training on performance.

Research methods. In the first study, 67 high-level young basketball players performed a shuttle-run test (SRT) to measure their VO_2max. Competition performance assessed through statistics ratings of 5 matches was determined for all players. The correlation between VO_2max and performance was calculated. In the second study, the VO_2max and the competition performance of 34 high-level young male players was assessed as in the first study. The sample was divided into control and experimental groups, which trained their VO_2max. At the end of the training period all participants repeated the SRT. The results of 4 games played before the first test and 4 games played after the second test (against the same opponents) were compared in both groups.

Research results. In the first study we found a correlation of VO_2max with steals in both groups. In the second study, the experimental group increased their VO_2max and steals per game, but they decreased free throw per game and free throw percentage.

Discussion and conclusions. No correlation was found between VO_2max and competitive performance in this study, and increased VO_2max had no effect on most of the studied variables. The data therefore suggest a non-linear relationship between VO_2max and basketball performance.

Keywords: aerobic capacity, basketball performance, non-linear relationship.

INTRODUCTION

It is difficult to quantify players' performance in team sports due to the extreme complexity and variety of game actions. Traditionally, performance has been considered to be the sum of several aspects: physical level (endurance, strength, velocity, etc.), adequate technique, correct tactical decisions and self-control in pressure situations, etc. In recent years many tests have been developed to assess each of these components separately, the main objective being to monitor and train these capacities on an individual basis.

In order to quantify the performance of players in competitive settings the game is broken down into isolated actions that are later quantified. Game statistics, which are especially popular in baseball and basketball, determine the player's overall performance using several formulas (Berri, 2000). However, there are at least two key questions that require further investigation: is competitive performance equivalent to the sum of a limited set of isolated actions or to the sum of different qualities assessed through specific tests? Is there a linear relation between performance components and the competitive performance itself, i.e. would training and improving a single component (such as VO_2max) produce a concomitant improvement in the overall competitive performance?

One of the main indicators of the level of aerobic capacity development is VO_2max. Its importance in competitive performance is well-known and rests on the relationship between aerobic capacity and both repeated sprint ability (RSA) and phosphocreatine levels (Bishop et al., 2004). In addition, a decrease in intracellular pH due to low aerobic capacity may also contribute to the decline in power output during RSA via inhibition of glycolysis (Westerblad et al., 2002). Thus, the main aim of a typical physical training programme in team sports is to increase aerobic capacity together with strength and speed, which would be expected to improve the player's overall performance. The relationship between increased VO_2max and the total distance ran and the distance covered at high-running speed has already been studied in soccer (Impellizzeri et al., 2005). In competitive basketball, especially in young players, an increase in VO_2max levels seems crucial because of the fast movements performed throughout the game and the fact that aerobic metabolism is the predominant energy source (Abdelkrim et al., 2007). Consequently, we hypothesise that an increase in VO_2max will have an effect on match performance.

Although it is commonly assumed that there is a linear relationship between physical condition components and performance, some recent experiments have shown non-linear relationships between these components: for example, between strength training and aerobic capacity (Paavolainen et al., 1999) and speed and strength (Wisloff et al., 1998), among others. It is therefore unclear whether an increase in VO_2max will produce a linear improvement in the performance of a basketball player, as there may be interactions with other components. This is a common effect in complex adaptive systems the behaviour of which being the result of an immense number of coordinated spatio-temporal processes, is highly non-linear (Hristovski et al., in press). In other words, their macroscopic behaviour (e. g. their performance) is a collective effect of sets of highly interdependent components within the system, i.e. a result of their synergy in space and time.

The aim of this study was therefore twofold:

A) To study the correlation between individual basketball performance (assessed on the basis of basketball statistics) and aerobic capacity in young high-level basketball players.

B) To study the effects of aerobic capacity training on competitive performance in the same population.

RESEARCH METHODS

FIRST STUDY

Participants. Sixty-seven male elite basketball players (mean age 12.89 ± 0.49 years) belonging to six different teams participated in the study. They were all informed about the study characteristics and signed a written consent form. The sample was divided into two groups: Group A comprised 33 players aged 13 years, while Group B included 34 players aged 12 years. They all engaged in a total of 4.5 hours of basketball training per week, as well as 3 hours per week of physical training.

Procedure. In both groups VO_2max was estimated through a 20 m SRT performed on two occasions, five weeks apart. The formula used was: VO_2max (ml / kg · min) = 31.025 + 3.238 · speed in km / h – 3.248 · age + 0.1536 · speed in km / h · age (Léger et al., 1988). All participants wore a portable heart-rate monitor to test their maximum heart rate, thereby ensuring maximum effort. Before each test, height and weight was measured to ensure that any possible modification in aerobic capacity would not be due to morphological changes.

Between the first and the second test the participants played five matches, all of which were statistically analysed. A total of 30 matches were studied and the evaluated variables were: points, rebounds (offensive, defensive and total), assists, blocks, blocks received, steals, turnovers, 1, 2 and 3 field goals (missed, made and attempted), personal fouls, and personal fouls received.

Data analysis. In order to compare different teams the data were standardised to 100 team ball possessions (Góme, Lorenzo, 2008) using the following formula: Team ball possessions = field goal attempts + 0.5 · free throw attempts – offensive rebounds + turnovers.

These data were then used to calculate the player efficiency rating by applying the ACB League formula (Martínez J. A., Martínez I., 2010): ACB League Rating = points + assists + blocks + steals + received fouls + field goals made + 3 points field goal made – received blocks – turnovers – missed free throws – field goal attempted – personal fouls.

Descriptive statistics of height, weight, VO_2max HRmax and performance formulas were then calculated. To ensure a normal sample distribution the Shapiro-Wilks test was applied. The significance of any differences between the first and the second VO_2max tests was assessed by means of the Student's *t* test. Finally, we calculated the *r* value for the correlation between match performance and aerobic capacity. Statistical significance was set at $p < 0.05$.

RESEARCH RESULTS

Tables 1 and 2 show the descriptive statistics of height, weight, VO_2max, HRmax and the performance indicators for both groups. There were no significant differences between the first and second SRT, neither in terms of VO_2max (Group A: p = 0.295; Group B: p = 0.332) nor HRmax (Group A: p = 0.658; Group B: p = 0.498). These results indicate that aerobic capacity did not change significantly in the five-week period between the two tests.

Table 2 shows the correlations between VO_2max and basketball performance in terms of the statistical variables. Only "steals" showed a positive correlation in both groups (Group A: r = 0.434; Group B: r = 0.661), while the other correlations were very low.

SECOND STUDY

Participants. Three teams comprising 34 elite basketball players (mean age 12.49 ± 0.49 years) participated in this study. All subjects were informed about the purposes of the study and gave their written consent. The sample was divided into two groups: Group E (aerobic training) included 14 players, while Group C (control group) comprising the remaining 20 players.

Procedure. VO_2max was determined by the SRT, similarly to the procedure in the first study. Each team was divided into two homogenous groups according to their initial aerobic capacity. Both groups engaged in 4.5 hours of basketball training per week, plus 3 hours of physical training. In addition, Group E performed aerobic capacity training three times per week over a six-week period. Overall, Group E trained each week for approximately 1 hour 30 minutes more than Group C. The aerobic capacity training consisted of series

Table 1. **Descriptive data for both groups**

Groups \ Variables		Height, cm	Weight, kg	HRmax, beats / min	VO_2max, ml / kg·min
Group A (n = 33)	Mean (± SD)	174.48 (± 10.23)	61.68 (± 11.51)	202.7 (± 6.49)	51.44 (± 4.7)
Group B (n = 34)	Mean (± SD)	167.47 (± 10.9)	56.77 (± 11.2)	203 (± 8.52)	49.5 (± 5.33)

Table 2. **Correlations between VO_2max and basketball performance assessed according to competitive statistics**

Group \ Variables	Minutes played	Points per game	Personal fouls per game	Personal fouls received per game	Rebounds per game	Defensive rebounds per game	Offensive rebounds per game	Steals per game	Blocks per game	Assists per game	Turnovers per game	Free throws made per game	Free throw attempts per game	Free throw percentage	2-points made per game	2-point attempts per game	2-point percentage	3-points made per game	3-point attempts per game	3-point percentage	ACB League formula
A	0.146	0.079	0.165	–0.116	–0.249	–0.218	–0.430*	0.434*	–0.191	0.29	–0.079	–0.102	–0.344	0.258	0.365	0.349	0.146	0.235	0.134	0.216	0.069
B	0.132	0.263	–0.113	0.173	0.078	0.095	0.04	0.661**	0.117	–0.01	0.18	–0.113	–0.001	0.046	–0.038	–0.151	0.14	0.262	0.094	0.356	0.389*

Note. * – p < 0.05 ** – p < 0.01

of 7–10 min at 65–75% of VO_2max, 4–5 min at 70–85% of VO_2max and 2–4 min at 90–120% of VO_2max. The rest period between series lasted between 1 min and 5 min. A second SRT was performed at the end of the training period.

As in the previous study, basketball statistics were determined according to team ball possessions. Each player's competitive performance was established on the basis of statistics derived from four matches played before the first test and four matches played after the second test. These four pre and post matches were played against the same teams.

Finally, descriptive statistics of height, weight, VO_2max, HRmax and the performance indicators were calculated. To ensure a normal sample distribution the Shapiro-Wilk test was applied. The significance of any differences between these variables at the first and second testing points was assessed by means of the Student's *t* test. Statistical significance was set at $p < 0.05$.

RESEARCH RESULTS

Table 3 shows the descriptive statistics of height, weight, VO_2max, HRmax and the performance indicators for both groups. The pre- and post-training VO_2max values for the experimental group were 50.9 ml / kg · min and 53.98 ml / kg · min, respectively, this difference being statistically significant ($t = –6.31$; $p < 0.01$). There was also an increase in the number of steals per game ($t = –2.27$; $p < 0.05$), coupled with a decrease in both the number of free throws made ($t = 2.40$; $p < 0.05$) and the percentage of free throws ($t = 2.96$; $p < 0.05$). In the control group none of the variables changed significantly.

DISCUSSION

The first study found no correlation between aerobic capacity and the ACB League player efficiency rating in the group of 13-year-olds,

Table 3. **Values of the variables studied in the experimental and control groups before and after the aerobic capacity training period**

Variables \ Group	Experimental		Control	
	Before	**After**	**Before**	**After**
Height	171.21 (± 11.07)	172.88 (± 11.01)	170.21 (±12.81)	171.95 (± 13.15)
Weight	60.35 (± 12.69)	61.63 (± 12.71)	60.14 (±14.22)	61.77 (± 14.17)
VO_2max (ml / kg · min)	51.89 (± 5.29)	55.18 (± 4.92)**	52.66 (± 4.65)	53.22 (± 3.57)
HR_{max}	200.61 (± 8.22)	201.15 (± 8.32)	207.18 (± 7.60)	207.31(± 7.21)
Minutes played	19.04 (± 2.35)	19.83 (± 2.35)	19.40 (± 2.37)	20.98 (± 1.70)
Points per game and player	13.17 (± 5.52)	12.84 (± 5.80)	11.83 (± 5.74)	12.16 (± 6.98)
Personal fouls per game and player	1.82 (± 0.61)	1.64 (± 0.65)	1.91 (± 0.70)	1.59 (± 1.01)
Personal fouls received per game and player	1.60 (± 0.75)	1.54 (± 0.66)	1.79 (± 0.79)	1.94 (± 1.13)
Rebounds per game and player	4.48 (± 3.40)	4.61 (± 3.24)	3.17 (± 1.69)	3.04 (± 1.63)
Defensive rebounds per game and player	2.87 (± 1.01)	2.74 (± 1.28)	2.35 (± 1.12)	1.83 (± 1.02)
Offensive rebounds per game and player	1.60 (± 2.19)	1.87 (± 2.17)	0.83 (± 0.75)	1.21 (± 0.93)
Steals per game and player	2.79 (± 2.40)	3.87 (± 2.22)*	3.01 (± 1.68)	3.5 (± 1.55)
Blocks per game and player	0.08 (± 0.12)	0.38 (± 0.35)	0.23 (± 0.26)	0.09 (± 0.22)
Assists per game and player	2.19 (± 1.31)	1.88 (± 1.45)	1.73 (± 1.19)	2.16 (± 1.65)
Turnovers per game and player	1.47 (± 0.79)	1.89 (± 0.89)	1.36 (± 0.58)	1.73 (± 0.54)
Free throws made per game and player	1.38 (±0.06)	0.95 (± 0.06)*	1.27 (± 0.67)	1.23 (± 0.89)
Free throw attempts per game and player	2.23 (± 0.89)	2.15 (± 1.29)	2.13 (± 1.07)	2.14 (± 1.34)
Free throw percentage	61.93 (± 21.48)	44.02 (± 17.4)*	59.43 (± 34.59)	57.19 (± 22.15)
2-points made per game and player	5.48 (± 2.5)	5.74 (± 9.2)	4.77 (± 2.60)	4.18 (± 3.09)
2-point attempts per game and player	8.2 (± 3.15)	8.43 (± 12.49)	7.42 (± 3.47)	6.25 (± 4.13)
2-point percentage and player	66.87 (± 15.9)	68.07 (± 11.22)	64.25 (± 12.35)	66.89 (± 14.40)
3-points made per game and player	1 (± 1.25)	0.9 (± 1.26)	1.16 (± 1.47)	1 (± 1.54)
3-point attempts per game and player	2.4 (± 2.76)	2.5 (± 3.21)	2.66 (± 3.11)	2.88 (± 3.23)
3-point percentage	41.67 (± 33.48)	36 (± 34.54)	43.61 (± 34.52)	34.72 (± 38.46)
ACB League formula	17.10 (± 7.29)	17.33 (± 7.30)	14.56 (± 8.17)	14.93 (± 9.73)

Note. * – $p < 0.05$, ** – $p < 0.01$.

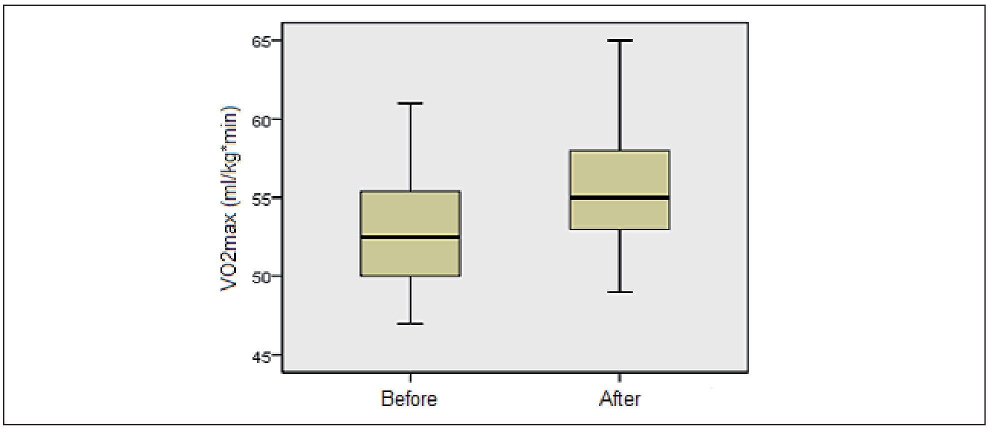
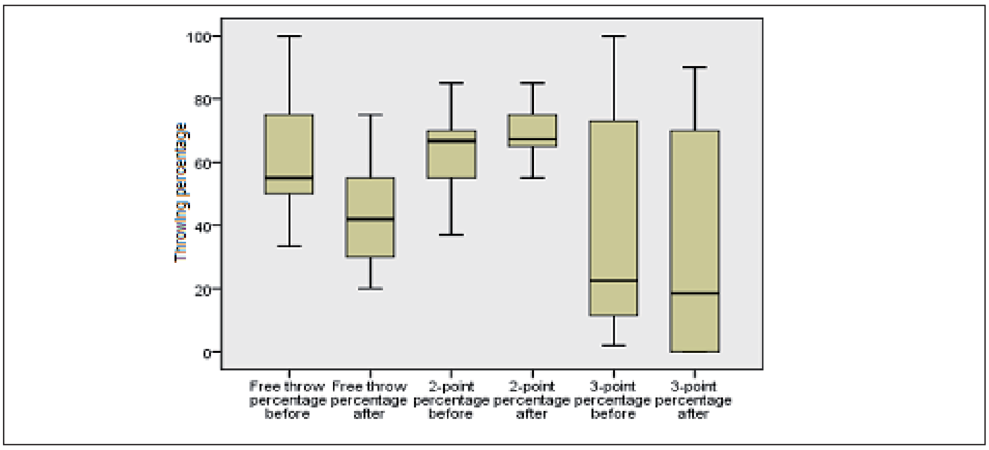


Figure 1. **VO_2max before and after the aerobic training period in the experimental group**



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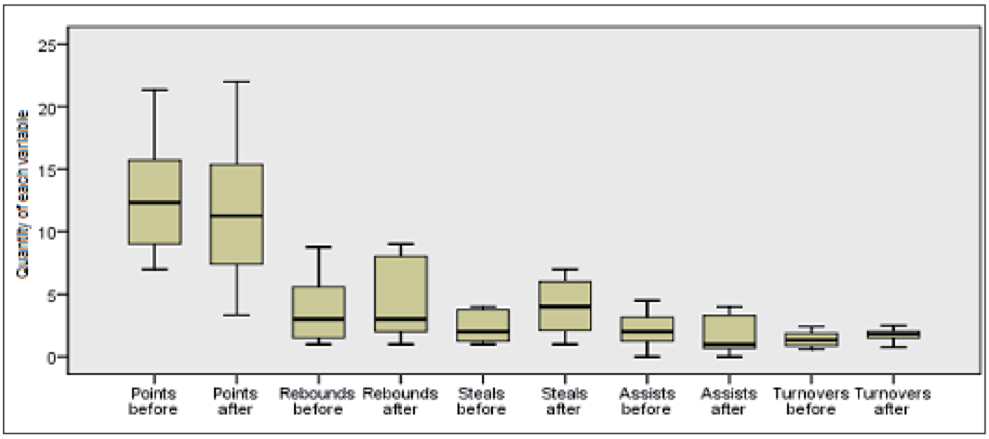


Figure 3. **Most notable basketball statistics before and after the aerobic training period in the experimental group**

while the correlation was very low among the 12-year-olds. There was a moderate correlation between aerobic capacity and the number of steals in both groups, and a low negative correlation with offensive rebounds in the group of 13-year-olds. In the second study the increased aerobic capacity of the experimental group had no effect on most of the variables studied. Specifically, it only had a positive effect on the "steals" variable, while there was a negative effect on the number of free throws made and the free throw percentage.

The basketball variables studied were those usually analysed in national and international championships. The ACB player efficiency rating is one of the most widely used in European basketball, despite there being other formulas (Manley, 1989), all of which are highly correlated with ACB ratings (for example, those of the NBA; $r = 0.98$).

The 20 m SRT is an indirect test that shows a high correlation ($r = 0.89$) with real aerobic capacity in children (Léger et al., 1988). The VO_2max values found here were higher than those reported in a population of a similar age (Mota et al., 2002), although to our knowledge there are no similar studies about the aerobic capacity of young male elite basketball players.

In the first study the only variable that correlated with VO_2max was the number of steals ($r = 0.434$ and $r = 0.661$ in groups A and B, respectively). This is probably due to the pace at which basketball is played by 12–13-year-olds. The six participating teams utilised pressing defences with guard and forwards during all the matches. Guards tended to have a higher aerobic capacity than do forwards and centres. However, we did not classify the players according to their position due to their versatility at this age. Correlations between aerobic capacity and both the ACB efficiency formula ($r = 0.389$; $p < 0.05$) and the number of offensive rebounds ($r = 0.430$; $p < 0.05$) were very low, indicating the weak association between VO_2max and these variables. These results suggest that in a high-level basketball group, aerobic capacity is not related to competitive performance.

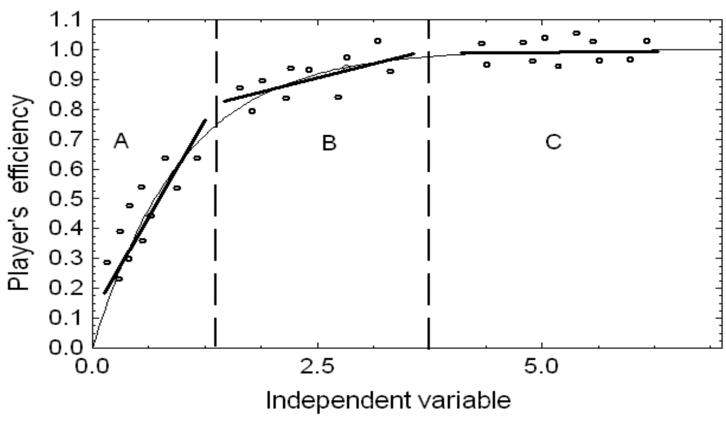
It should be noted that some studies have found a correlation between VO_2max and soccer level. U. Wisloff et al. (1998) found a significant difference in VO_2max between the top and lower placed teams in the elite Norwegian division. Other studies in soccer have found a relationship between VO_2max and the number of sprints and high-intensity running (Krustrup et al., 2005), as well as between the total distance covered during a match and the aerobic capacity (Bangsbo, Lindquist, 1991). However, some authors have argued that the total distance covered during a soccer match seems to be a poor indicator of soccer performance (van Gool et al., 1988). Other factors such as the number of correct passes, correct tactical decisions, and adequate sport technique seem to have a greater effect than VO_2max on match performance.

In the second study the experimental group underwent aerobic capacity training according to the criteria established in the literature for this age group (Payne, Morrow, 1993). Three days per week over a six-week period is the minimum standard for any aerobic training programme. The increase obtained in aerobic capacity (from 51.89 to 55.18 ml / kg · min; $p < 0.01$) represents an increase of 6.3%, which is consistent with the results obtained in other studies that have reported similar responses to aerobic training in children (Payne, Morrow, 1993).

A recent study has reported that points, field goal percentage, assists and defensive rebounds are the most relevant statistical variables in basketball (Ibáñez et al., 2008). The present study found no change in any of these variables after the aerobic training (Table 3 and Figures 2 and 3), and it therefore seems that an increase in VO_2max is not associated with better competitive performance. We did observe an increase in a less important statistical variable, the number of steals per game (2.79 vs. 3.87; $p < 0.05$), although this is probably due to the guards' pressing defence. In the present study, aerobic training was also associated with a decrease in both the free throw percentage (61.93% vs. 44.02%; $p < 0.05$) and the number of free throws made per player (1.38 vs. 0.95; $p < 0.05$). The importance of the free throw percentage is minimal in unbalanced games, but it is very strong in the balanced ones (Gómez et al., 2008).

A possible explanation for our results is the detrimental effect that excess aerobic training can have on strength and speed (McCarthy et al., 1995). Unfortunately, we did not evaluate other physical capacities in order to check for possible interferences. Another point to note is that the relationship between aerobic capacity and exercise

Figure 4. **A schematic representation of possible types of experimental results**



Note. The relationship of dependence between a player's efficiency and a given independent variable is non-linear, shown by the thin continuous line. A piece-wise linear approximation: A – there is a strong, approximately linear dependence; B – a weak, approximately linear dependence; C – there is no dependence. While in A and B the change in a player's efficiency is proportional to the changes in the independent variable, in region C this proportionality breaks down. Circles simulate a data scatterplot.

recovery appears to have certain limitations. In a study of infantry soldiers performing the line drill, J. R. Hoffman (1997) found that the fatigue index was significantly higher in soldiers who had aerobic fitness levels that were one and two standard deviations below the population mean. However, as aerobic fitness improved, no further benefit in the fatigue index was observed. This is suggestive of a clear non-linear saturation effect (Fig. 4). In contrast to our results, some authors have found that greater aerobic capacity leads to an increase in the total distance covered during a soccer game, as well as the time played at high intensity (Impellizzeri et al., 2005). The main problem with these studies is that the number of matches analysed was very low, and these improvements could have been influenced by several factors, including the importance of the match, the skill level of the opposition, seasonal variation and the tactical approach used (Stone, Kilding, 2009). Other aspects related with the player's position may also affect the results.

In fact, frequent inconsistencies of research results accumulated over the years may mean that relationships among the variables defining athletic abilities are context dependent, and also that both the training process and population differences strongly constrain and shape the matrix of associations between the capacities studied. Hence, inter-variable relationships emerge under constraints, and the tacitly held assumption of invariant structural relationships, which should be discovered by cleverly performed experiments, may be a dead end. If this is so, then researchers need to turn their attention to the study of constraint effects.

CONCLUSIONS AND PERSPECTIVES

In summary, the present results do not corroborate a linear relationship between physical conditioning components and competitive performance, and throw into question the excessive aerobic training programmes administered to young elite basketball players. The context dependency of competitive performance and the non-linear interactions between physical capacities point to the need to study these phenomena under the framework of non-linear dynamic systems theory.

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AEROBINĖ TRENIRUOTĖ NEPAGERINA JAUNŲ DIDELIO MEISTRIŠKUMO KREPŠININKŲ VARŽYBINĖS VEIKLOS

Carlos Claramunt[1], Ivar Guzman[1], Joan Solé[1], Natàlia Balagué[1], Robert Hristovski[2]
Barselonos universitetas[1], Barselona, Ispanija,
Šv. Kirilo ir Metodijaus universitetas[2], Skopjė, Makedonija

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Kai kurie autoriai mano, kad komandinio sporto žaidėjai turėtų būti didelio aerobinio pajėgumo, kiti – kad per didelis ištvermės ugdymas gali pakenkti tokiems fizinės būklės komponentams kaip jėga ar greitis.

Tikslas: nustatyti jaunų krepšininkų žaidimo ir VO_2max rodiklių koreliaciją ir įvertinti, kaip aerobinio pajėgumo ugdymas veikia ją.

Metodai. Pirmo tyrimo metu didelio meistriškumo krepšininkai (12–13 m. amžiaus) atliko šaudyklinio bėgimo testą ir pamatuotas jų VO_2max. Tiriamieji buvo padalyti į A (33 trylikamečiai) ir B (34 dvylikamečiai) grupes. Įvertinta visų žaidėjų varžybinė veikla pagal penkių rungtynių statistinius reitingus. Apskaičiuota koreliacija tarp žaidėjų VO_2max ir krepšinio žaidimo rodiklių. Antru tyrimu nustatyti 34 didelio meistriškumo krepšininkų (trylikamečių) aerobinio pajėgumo ir varžybinės veiklos rodikliai taip, kaip ir per pirmą tyrimą. Tiriamuosius padalijome į kontrolinę ir eksperimentinę grupes. Pratybų pabaigoje visi tiriamieji pakartojo šaudyklinio bėgimo testą. Tada palyginome abiejų grupių ketverių rungtynių rezultatus prieš pirmą testą ir po antro (žaidžiant pries tuos pačius varžovus).

Rezultatai. Pirmu tyrimu nustatyta VO_2max ir atkovotų kamuolių skaičiaus koreliaciją abiejose grupėse. Antro tyrimo metu eksperimentinės grupės žaidėjų VO_2max rodikliai buvo geresni ir per vienas rungtynes jie daugiau atkovojo kamuolių, tačiau metimų skaičius per vienas rungtynes ir jų procentas sumažėjo.

Aptarimas ir išvados. Neaptikome jokios koreliacijos tarp jaunų didelio meistriškumo krepšininkų aerobinio pajėgumo ir varžybinės veiklos rodiklių, o padidėjęs aerobinis pajėgumas neturėjo jokio poveikio daugumai tirtų kintamųjų. Dėl to tyrimo rezultatai rodo netiesinį ryšį tarp VO_2max ir krepšinio žaidimo rodiklių.

Raktažodžiai: aerobinis aktyvumas, krepšinio žaidimas, netiesinis ryšys.

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Corresponding author **Carlos Claramunt Aguayo**
Institut Nacional d'Educació Física de Catalunya
University of Barcelona, Spain
Can pujolet street, 19-21, 2nd 1st. CP: 08032
Barcelona
Tel 610878083
E-mail carlostortosa21@hotmail.com