Effects of a neuromuscular training program on the maximal Oxygen consumption and vertical jump in beginning volleyball players

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ABSTRACT

The alterations that occur in the motor performance of young athletes involved in specialized trainings are not yet quite clear. That is a highly important knowledge to the appropriate prescription of the trainings. The purpose of this paper was to verify the influence of the training on the neuromotor and organic variables in young volleyball athletes in different moments of the program. Nine female athletes of the child team from Clube de Campo Piracicaba/SP were selected to perform the tests: the attack and blocking range, and the 1,000 meters test, with the purpose to assess the suggested training program in three different moments of the suggested training program. Four data collection were performed: the first on the athletes' presentation, the second one at the end of the general phase, and the third at the end of the special phase, and the last one at the end of the competitive period. In the preparatory period, the exercises were used aiming to improve the athletes' performance to accomplish the motor actions of the game. During the competitive phase, it was performed exercises with the purpose to keep the previously attained output indexes, favoring the collective exercises involving the techniques and tactics of the modality. Based on the statistical analysis of the data attained through the calculation of the mean, the standard deviation significance level ($p < 0.05$), and the percentage of the data, it was possible to conclude that there was an increase in the strength indexes of the lower limbs and in the general endurance during the general phase of the preparatory period; in the special phase, the increasing bias continued. During the competitive period, the results achieved were maintained, and this confirms the effectiveness of the training program suggested for the physical capabilities assessed.

Keywords: Evaluation in volleyball. Training. Adolescent and volleyball. Strenght in volleyball.

INTRODUCTION

The involvement of young athletes in specialized and intense training processes aiming to acquire a high output and to participate in high level competitions has been an increasing concern among the community connected to the sportive sciences[1].

One of the main reasons to such concern is found in the biological-sportive diversity of children and adolescents compared to the adults'. In that phase, it appears several alterations and physical, psychological, and psychosocial particularities that provoke consequences on the corporal or sportive activity, and therefore, to the athlete's skills in the load bearing. Due to this, the adolescence period must be used towards the improvement of the specific sportive modality techniques, and to acquire the specific condition necessary to that sportive modality[2]. It is in that very moment that it occur the favorable conditions to develop all the physical skills, through rational, pedagogic, and systematic actions. Such actions must not change the development of another motor function of the individual. The pedagogic action to develop the physical skills contributes to the major appearance of one of them[3].

Studies aiming the endurance analysis present an important anatomic modification that happens during the puberty, which is the development of the heart volume. Upon the assessment of the heart volume by means of X-Rays in 159 German high-medium class students, it was verified that the heart volume had a 64% increase between the 10 and 16 years old individuals[4]. That information shows the possible improvement for the motor endurance, mainly the cardiorespiratory type, on that age level.

The metabolic and hormonal responses to the exercise in children and adolescents show that they are more fitted in to the aerobic exercises due to the predominance of the strength source used in the exercise is more connected to oxidative metabolism than for adults.

The glycolytic activity depends on the age and to the proportional utilization of the fat during prolonged exercises seems to be higher in children than in adults[5].

In such sense, researchers of the growing and development point out that optimum phase to train this ability occurs during the pulling up of the puberty growth, in the first pubertal phase (an anterior phase to the arrival of the menarche). During that period, the size and weight of the heart (almost the same that occurs in the lungs) have a maximal increasing rate, and the relative heart volume reaches its peak value. The cardiopulmonary system is in an excellent phase of its development, showing itself highly trainable[2].

Other capabilities, such as the maximal aerobic power, has its development during the puberty, that is, it attains its maximal potential values when they worked out before and after the pubertal phase. The anaerobic ability attains its maturation by the time the puberty starts, and it is extended for a few years, after the adult age[6]. The strength has its period for a better trainability in the second pubertal phase (adolescence). At that moment, there is a major development of the width, and parallel, a strong increase in the musculature[7].

Through a comparison between a group of early maturity girls or more lately in skeletal terms, it seems that both groups can attain similar levels of strength at the end of the adolescence, although apparently through different ways. If by one side girls with early maturity show a fast strength development, on the other hand, girls with late maturity have an increased strength with a lower but gradual intensity from the age of eleven years old up to

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the end of the adolescence period[8]. Carron *et al.*[9] assert that such bias seems to be real to girls that experience the menarche in their earlier ages.

The interval between ± 1 year after the peak height velocity is mentioned as a sensitive period to the development of the muscular strength. It is obvious that higher amounts of muscular strength occurred one year ahead the peak velocity of the height, coinciding with the peak velocity of the weight, one of the major causal agents to such behavior. The increasing testosterone level and insulin factor to the type 1 growth (IGF-1) which is mediator for the growth hormone during that period are also responsible by those higher values[10]. The physical activity seems to influence the plasmatic and muscular levels of the IGF-1 according to the age, diet, type and intensity of the exercise worked out[11].

The muscular strength has an extended of almost stability period to both genders. When the pubertal period is about to start, the development starts, and it is extended along that phase, attaining its maturity in the adult status. It must be observed that the physical ability is considerably accentuated in the male gender[6].

Although a portion of different muscular groups show different development levels, it can be determined that girls attain their maximal peak approximately at 15-17 years old[12].

Between 10 and 16 years old, there is a growth in the level of the jumping strength in boys, and there is a similar fact with girls. There is no moment when that skill presents a retrocession. The growth portions in boys are higher to the portions girls presented. The development of other motor strength manifestations are similar to the previous conclusions on the jumping strength, clarifying that it is impossible to talk about a decrease in the output before 16 years old[13].

Added to the fact that there is no output decrease, Fleck and Kraemer[14] observed a reduction of injuries in the sportive field associated to the increase in the voluntary muscular strength, in the explosive power, and in the muscular mass in several strength training programs.

As to the training loads and methods, during the adolescence it can be widely used the same loads than the adults do, provided it is performed in an adapted form or the proportions is strictly respected. There is a concern since that type of training might damage the cartilages of the bone epiphysis along the growth period, and this may result in deformities and growth stagnation[15]. During that age level, it must predominate the comprising work instead of high intensity loads; furthermore, the continuous load increase represents a further essential basic principle to the strength training[2].

Considering the points stated above, it is observed positive effects on the strength and endurance parameters in girls passing by the transitional phase from the adolescence to the adult phase, mainly in those individuals involved in training programs. Nevertheless, it is not clear how these effects occur in the different phases of the training program application.

It is believed that the further investigation of these effects along with the suggestion of a training program will contribute to the understanding on the trainability limits for young athletes seeking the excellence performance in the adult age.

The purpose of this study was to assess the application of a training program based on specific neuromuscular trainings to verify the maximal consumption modifications of Oxygen and in the vertical jump at different moments of the training program in a female volleyball team with ages from 14 to 15 years old.

METHODS

The sampling was composed by nine 14 to 15 years old female athletes, five of them from the child category (14 years old), and four from the junior high category (15 years old), all of them with few experience in the modality (one year or less participating in the trainings). In the year when the research was performed, those volunteers were training five days a week, three hours a day, and they were playing for the volleyball team of the Clube de Campo de Piracicaba in the Piracicaba city, São Paulo State.

That team participated in regional competitions organized by the Pro-Volleyball Association – APV in the child and junior high categories. Along the year when the analysis was performed, the child team conquered the Championship of the Silver series. Those athletes participated in approximately thirty-five games, six in the first phase, from April to June, six in the second phase, from August to November, three in the final phase of the championship of their category in the third week of November, and twenty other games in the championship of the junior high category.

The junior high team conquered the Championship of the Cupper series. Those junior high athletes participated in approximately twenty games along the year of the research, six in the first phase from April to June, ten in the second phase, from August to November, three in the last phase in the last week of November, and some other friendly games.

The technical committee of the team was in charge for every schedule of the championship, and the training periodicity was approved in the beginning of the year by the Ethics Committee of the Sports Department from the Club (CEDE), having as requirement that the participant teams and their care-takers should acknowledge the content of a "Free and Clarified Consent Term", according to recommendations contained in the 196/96 Resolution from the National Health Council to integrate the team.

Athletes and their care-takers signed the term agreeing with its content, and that every data obtained from their assessment and trainings could be analyzed from the club files for this research.

It was applied a questionnaire requesting the athletes' information for a better sampling characterization.

The volunteers began to practice any sportive activity around 9.2 (± 2.9) years old. The amount of participation in Physical Education classes at school was around 1.8 (± 0.4) times per week.

All of them have already had their first menstrual period, the menarche, and the mean age of that occurrence was 11.7 (± 1.0) years old, that means, at least one year before she joined the team. The menarche has a time correlation with stages of the mammary development. According to the Tanner's[16] classification, it occurs when the girl is between her 4 and 5 stages. Following this information, it seems correct to state that every involved athlete was in the final stage of their biological maturity towards the adult age.

The mean age to begin the volleyball practice occurred at 11.3 (± 1.0) years old and the amount of participation in tournaments or championships was of 2.0 (± 0.6) events up to the beginning of this study.

The athletes were followed up in their trainings for an eight months period, amounting thirty-four weeks of follow-up. Along that period, the specific trainings were constituted by jumps, medicine ball throwing, and weight-exercises in the fitness room, along with the technical and tactic trainings on the court, following the periodicity proposed to 2003.

The structure of the training periods adopted was based on well-known international theories[17-20] in which the yearly training cycle is divided in three periods: the preparatory period, where the aim is to develop the sportive fitness; the competitive period, aiming to keep the sportive fitness, and the transitional period, that is the moment when there is a decrease in the sportive activity.

The preparing macro-cycle was elaborated aiming to achieve the peak of the sportive fitness at the end of the training cycle – weeks 26 to 34, when the athletes participated in the final competitions.

The transitional period occurred in December, January, and February.

To the volume (VOL) and intensity (INT) controlling of the periodization phases the load used in the physical trainings were considered the general exercises, the loads used in the technical trainings were considered the special exercises, and the load used in the tactic trainings were considered the competitive exercises.

The competitive exercises were performed at high ALT and low VOL, as they were simulations of the game itself. The special exercises were also performed at high INT, but as they were exercises with partial features of the game, they allowed the use of higher VOL. The general exercises were performed at a lower INT and high VOL.

During the training sessions, the number of repetitions and series of the exercises to be performed in the physical, technical, and tactic training were used to control the VOL. The time destined to perform the exercise, that is, the pause between repetitions, the recovery time, or the pause between series, the load used in exercises using external load to the body weight, and the jumping height in the plyometry exercises were used to control the INT.

The distribution curve of the general, special, and competitive exercises along the macro-cycle is described in the figure 1.

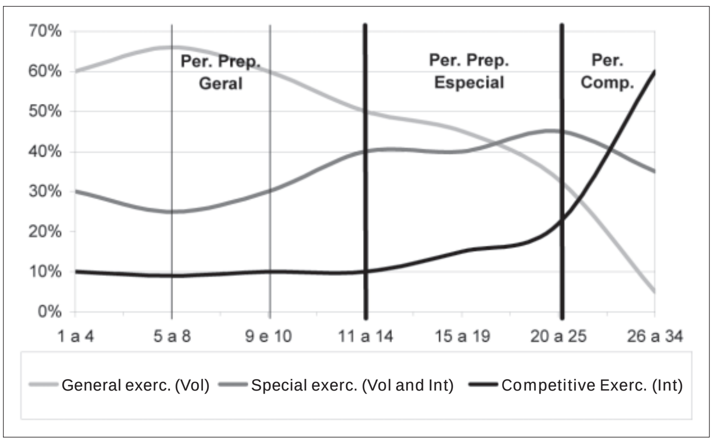

Fig. 1 *– Distribution of the load timetable to the general, special, and competitive exercises along the macro-cycle assessed*

Assessments were performed in four different moments. The first assessment was performed on the athletes' presentation. The second assessment was performed in the end of the general preparatory period, the third assessment was performed in the end of the special preparatory period, and the forth and last was performed in the end of the competitive period.

In order to assess the vertical jump, it was used the range of the maximal blockage height, when the athlete started the test in a straight position, having her whole feet supported on the ground, semiflexed arms ahead on her trunk having both hands at her shoulders height (initial positioning to the blockage). From a knee semiflexion, it was performed a fast eccentric/concentric transition of the knees, and the athlete immediately performed a jump as vertical as possible, touching the wall with her both hands' middle finger tip. The blockage range height was recorded using meters.

Still, it was used the maximal attack range where the athlete performed an three-footstep approximation running oblique to the wall in a 30 to 45º according to the individual choice. After the "attack call" (right/left) in both feet, the athlete performed a vertical jump searching for her maximal vertical raise; left-handed athletes inverted their starting position. The height of the attack range was recorded using meters.

In order to determine the maximal Oxygen consumption ($\dot{V}O_2$ max), the 1,000 meters test of the Klissouras[(21)]'s protocol was used, where the athlete started from the standing up position answering the "Attention: Ready" command, when she ran 1,000 meters in the fastest time possible, and she was not allowed to walk during the test. The running time was recorded using seconds, and the $\dot{V}O_2$ max value was calculated using the following formula: $X = (652.17 - Y)/6.762$, where: $X = \dot{V}O_2$ max in $ml/Kg/min^{-1}$; Y = running time of the 1,000 meters recorded in seconds; and 652.17 and 6.762 are constant factors of the formula.

RESULTS

Table 1 presents the mean values and standard deviation (SD) of the performances in the attack range test (vertical jump and running), blockage (steady vertical jump), and 1,000 m run, and the impulsion calculation of the attack and blockage, and of the $\dot{V}O_2$ max in the four moments of the assessment.

TABLE 1
Mean values and SD of the vertical jump motor (m) and 1,000 meters test in different moments of the assessment

Tests – Assessment moments	1st Assessment	2nd Assessment	3rd Assessment	4th Assessment
Attack range (m)	2.59 ± 0.11	2.64 ± 0.11	2.65 ± 0.11	2.65 ± 0.10
Blockage range (m)	2.49 ± 0.12	2.54 ± 0.10	2.56 ± 0.10[a]	2.56 ± 0.11[b]
Attack impulsion (m)	0.39 ± 0.03	0.42 ± 0.05	0.42 ± 0.06	0.43 ± 0.04
Blockage impulsion (m)	0.31 ± 0.04	0.34 ± 0.04	0.36 ± 0.04	0.35 ± 0.05
1,000 m (sec)	325.6 ± 16.2	338.7 ± 21.4	319.1 ± 30.2	319.4 ± 21
$\dot{V}O_2$ max ($ml/kg/min^{-1}$)	48.2 ± 2.4	46.3 ± 3.1	49.2 ± 4.4	49.2 ± 3.1

[a] P < 0.01 related to the 2nd Asses., [b] P < 0.05 related to the 2nd Asses.

There was a significant increase in the blockage range test in the third ($p < 0.01$), and fourth ($p < 0.05$) assessments compared to the second one. It was found no significant differences in the other measurements and tests among every assessment (table 2). The bias found in those results was a gradual increase up to the third assessment, and it was found a maintenance of the results in the fourth assessment.

TABLE 2
Results of the statistical test of the vertical jump motor test

Variable	P value (1st x 2nd)	P value (1st x 3rd)	P value (1st x 4th)	P value (2nd x 3rd)	P value (2nd x 4th)	P value (3rd x 4th)
Attack range (m)	0.68	0.68	0.68	0.68	1.00	1.00
Attack impulsion (m)	0.68	1.00	0.68	1.00	1.00	1.00
Blockage range (m)	0.37	0.22	0.37	**0.01**	**0.05**	0.37
Blockage impulsion (m)	0.22	0.22	0.22	0.18	0.50	0.45
1,000 m test (sec)	1.00	0.25	0.25	0.50	0.50	1.00
$\dot{V}O_2$ max. ($ml/kg/min^{-1}$)	1.00	0.25	0.25	0.50	0.50	1.00

The absolute (Abs) and percentual (%) differences between macro-cycle periods are described on table 3. The higher differences appeared in the general phase of the preparatory period. In the competitive period, the bias of the results was to maintain the values.

TABLE 3
Absolute and percentage differences in range and 1,000 m tests in different periods of the macro-cycle

Phases Tests – Differences	General		Special		Competitive	
	Abs.	%	Abs.	%	Abs.	%
Attack range (m)	0.05	1.89%	0.06	2.26%	0.06	2.26%
Blockage range (m)	0.05	1.97%	0.07	2.73%	0.07	2.73%
Attack impulsion (m)	0.03	7.14%	0.03	7.14%	0.04	9.30%
Blockage impulsion (m)	0.03	8.82%	0.05	13.89%	0.04	11.43%
1,000 m (sec)	–13.11	–3.87%	6.56	2.06%	6.23	1.95%
$\dot{V}O_2$ max ($ml/kg/min^{-1}$)	–1.94	–4.19%	0.96	1.95%	0.92	1.87%

DISCUSSION

The performance test for the blockage range showed a significant difference of $p < 0.01$ comparing the third (2.56 ± 0.1 m) to the second assessment (2.54 ± 0.1 m), and $p < 0.05$ comparing the fourth (2.56 ± 0.11 m) to the second assessment (2.54 ± 0.1 m). As to the attack range, there was no significant differences. These results agree with the Oliveira[22]'s findings in a study with eleven child-junior high athletes with ages between 15.8 and 17.1 years old. He found the occurrence of a general increasing bias in the performance in every test along the first macro-cycle (first training semester). To the vertical attack impulsion, Oliveira[22] did not detect any statistically significant differences. On the other hand, he found these differences in the blockage vertical impulsion.

Upon the analysis of the results found in the vertical attack impulsion test, Oliveira[22] found a percentage of raise in the first macro-cycle between 5.1 and 19.01%. In the second macro-cycle (second training semester), he found a negative percentual of alteration between –2.79 and –0.34%, and a posterior percentual raise in phases B and C between 3.61 and 6.03% during phase A. In the blockage vertical impulsion, the test found a percentual raise in the first macro-cycle between 9.37 and 22.19%. In the second macro-cycle, it was found a negative percentual alteration between –3.63 and –2.21% in phase A, and a posterior raise percentual of 2.01% in phases B and C.

In the present study, it was found a percentual improvement in the attack range test between 1.89 and 2.26%, a percentage between 1.97 and 2.73% to the blockage range, between 7.14 and 9.3% to the attack impulsion, and between 8.82 and 13.89% to the blockage impulsion, related to the results attained on the athlete's presentation.

These percentual differences found confirm what was found by Böhme and Kiss[23] who proposed to show the percentage evolution after a six months training period among one-hundred and five 10 to 17 years old young athletes participating in the Xerox/Cepusp Olympic Project. For female athletes, the impeller strength of the lower limbs had a 4.4 to 10.5% improvement, and these 4.4 to 10.5% improvement percentages had a variation among different age groups.

In the general phase of the preparatory period, the training based on multiple jumping seems to have allowed a major increase in every attack and blockage range macro-cycle of 0.05 in both tests. It is believed that such improvement is due to the intra- and inter-muscular improvement in the coordination, since it was less skilled athletes in the vertical jump performance. This fact is reinforced by Ugrinowitsch and Barbanti[24] who support the use of multiple jumps to incorporate several coordination elements to increase the ability of the muscular system in generating strength in a very fast way.

The lack of experience explains the difference found between the performance curves of the blockage and attack impulsion. The blockage jumping requires the incorporation of lower amounts of coordinating elements compared to the attack jumping. In this last one, the approach running and the arm's swinging at the very moment of the running are important elements to the performance, and this is an idea also supported by Smith[25], who points out that the refining of the jumping mechanics is one of the key-components to increase the skill towards the vertical jump ability.

The plyometric work along with the exercises to the strength development in the fitness room performed during the special preparatory period seems to be responsible by the improvement of the blockage impulsion, and this did not occur to the attack impulsion.

In the competitive period, the results attained during the preparatory period were kept. The bar squat and the technical-tactic trainings seem to be adequate to such maintenance. It is important to recall that Barbanti[13] supports it is impossible to speak about a decrease in the jumping strength output before the 16 years old. Due to this, the conclusion that the trainings performed in the previous period contributed to the improvement in the range and impulsion performance.

The only exception was the attack impulsion that presented an improvement in the performance. Oliveira[22] supports that the nature of the adaptation process in the sportive activity is not solely restricted to the growth in the motive power, but also to the higher athlete's skill in effectively using such power. Thus, it seems to be correct to explain such increase through a better utilization of the motor power attained in the previous phase, and such improvement was attained through a later coordination effect provoked by the increase in the repetitions of that fundament in the technical-tactic trainings with a consequent refining of the jumping mechanics.

It seems it occurred an improvement in the motor power verified through the increase in the blockage impulsion of 13.89% in the special phase of the preparatory period, and successively to a possible improvement in the athlete's ability in using such power, shown by the 9.3% improvement in the attack impulsion along the competitive period. In a research made with 13 to 19 years old young female basketball players, Bergamo[26] found a significant improvement in the vertical impulsion helped by the arms ($p < 0.01$) during three to six follow-up years when they were submitted to a 15 hours/week training. As to the vertical impulsion test with no help from the arms, it was found no statistically significant differences.

Related to the aerobic endurance, Böhme and Kiss[23] observed mean percentual increases that varied from 3 to 6% after a six months training. It was observed no similar results in this study, where the percentual variation was between –4.19 and –2.06%. That contradiction seems to be connected to the learning of the execution of the 1,000 meters running test. Three athletes succeeded in finishing the 1,000 m test during the presentation (3). This provoked an alteration in the presentation of the mean value of that assessment. Later, in the second assessment, all of them succeeded in accomplishing the test. Therefore, the mean value was below the other two assessments.

According to Filin[3], in the ages of 14 and 15 years old, girls are in a highly sensitive phase to develop the general endurance, and this is not in accordance to the negative variation found in the studies. It can be said that to use the 1,000 m test for such population, it is required at least three participations in the execution of the test, in order to eliminate the effects of the learning in the results.

The mean 46.35 and 49.25 $ml/Kg/min^{-1}$ values of the aerobic power found in our assessments showed higher values than the ones found by other researchers, and they did not present statistically significant differences between assessments. Bergamo[26] did not find also any significant difference related to the Oxygen consumption among young 13 to 18 years old basketball players along three to six years training 15 hours/week.

Cambraia and Pulcinelli[27] found a mean value of 38.34 $ml/kg/min^{-1}$ in athlete-girls with mean age of 14.88 years. Those authors pointed out the fact that for tennis, volleyball, and soccer, the amount in the resting period, measured in hours can be higher than during the performance of the exercise.

Kiss[28] also presented lower results than the ones found in a study with volleyball players with mean age of 14.52 years, and aerobic power of 33.20 $ml/kg/min^{-1}$. It is important to point out that in both studies with young volleyball athletes were used the twelve minutes test (Cooper Test), and this fact may influenced to the differences found.

Related to the training influence on the maximal Oxygen consumption, Nunes *et al.*[29] observed a significant increase of 5% in male volleyball players along the competitive period. It is worthy to point out that these athletes participated in specific training along their physical preparation, aiming to develop their aerobic and anaerobic endurance. These results were in disagreement to what was found in this study.

Through such significant increase, Nunes *et al.*[29] has shown an interesting possibility to control the improvement of that skill. The training heart rate (HR) was controlled during the training. The purpose was to keep it within the HR observed in the anaerobic threshold and the one observed in the respiratory compensating spot in the trainings with aerobic predominance, and to keep it above the respiratory compensating spot on those trainings with anaerobic predominance. In order to use such control, it was required to perform tests aiming to found those HR thresholds.

CONCLUSION

The effects of this training program applied to young female volleyball athletes point out that it is appropriate whenever they are in the initial period to participate in a competition. These programs must take into account that 14 to 15 years old athletes still requires neuromuscular skills. In such sense, the training science has a relevant role in the preservation of the athletes' health, allowing a more structure upgrade to more intense competitive phases.

Based on the results found in this study, it seems correct to conclude that those trainings performed in the general phase of the preparatory period promoted higher increases in the blockage and attack range indexes. In the special phase, the bias to an increase continued, although they were lower than in the previous phase.

In the competitive period, it was observed the maintenance of the results in the blockage and attack range, and in the blockage impulsion. In the attack impulsion there was an increase promoted through the improvement of the jumping mechanics and through the higher amount of the repetitions of the attack gesture performed in the technical-tactic training of that period.

The use of the 1,000 m test to that population requires at least three training applications of the distance to the athlete's perception of the maximal velocity rhythm in order to eliminate the variation along the test, since they are less skilled athletes.

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