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Muscular strength of 9-18-year old volleyball athletes through computational dynamometry*

Patrícia Schneider[1], Gisele Benetti[2] and Flávia Meyer[3]

ABSTRACT

The objective of this work was to describe and to compare the isometric and isokinetic muscular strength at different maturational degree of boys and girls volleyball athletes. 66 healthy children and youth participated in the study in a competitive sportive training. From the 37 boys, 10 were prepubescent (PP), 15 pubescent (PU) and 12 postpubescent (PO). From the girls, 11 were PP, 13 PU and 5 PO. A computational dynamometer (*Cybex Norm*) was used to measure the isokinetic strength of the elbow flexion (FC) and the knee extension (EJ) at speeds of 60 and 90º.s^{-1}. The isometric strength was measured in the same exercises at angles of 60 and 90º (FC), and 45 and 60º (EJ). The analysis of variance ANOVA and the *post hoc* Tuckey test were used for the comparisons between gender and maturational degrees. The significance level was considered as $p < 0.05$. Among the maturational degrees, the older groups were always stronger than the younger groups for both genders. Among genders, the boys were stronger than girls only for group PO, at both angles of the isometric test of FC and in the isokinetic test at 90º.s^{-1}. In the isometric tests of EJ, the values were not significantly different for boys and girls, regardless the maturational degree. In the isokinetic tests, the boys were stronger than girls in groups PP and PO, at 60 and 90º.s^{-1}. These results suggest that the maturational degree is more determinant of muscular strength of volleyball young athletes than the gender.

Key words: Child. Youth. Sports. Anthropometric evaluation.

INTRODUCTION

The muscular strength may both reflect the health status and to predict the performance for a given sportive modality. Also for children and youth, this component has been emphasized, reflecting the large number of studies on the trainability of strength in children(1).

The muscular strength is important in many sports(2-5) and, specifically in volleyball, it is widely used(2,5-7). Volleyball is a sportive modality that requires power in the upper members (especially shoulders), lower members (jumps) and trunk, besides aerobic conditioning in order to stay in a game that could last for as long as three hours(8). The improvement of these abilities is quite important for a volleyball player, being the muscular strength many times the priority for the young athlete(8).

The muscular strength in the lower members is indispensable in volleyball, once without it the athlete runs the risk of lesions and low power jumps. Also due to the hundreds of jumps, the ligaments and the connective tissue may be injured, as well as the articulations, especially the knees. With regard to the upper members, the strength seems to be determinant for the team performance(5).

The muscular strength is important for the basic training of the volleyball athlete due to the future training overload and to the lesion prevention. Although traumatic lesions such as bone fractures and dislocations are not usual, there are a large number of lesions by overload due to jumps, attack jumps and defense jumps (“little fish”). These microlesions may lead to chronic problems that could last for the lifetime of athletes; thus, a training adequate program to reduce the risk of lesions becomes necessary.

The field tests are practical to evaluate the strength in children(9-11), however showing some disadvantages, once they disable the control of factors that may influence the

* Escola de Educação Física – UFRGS, Porto Alegre, RS.

1. Graduated in Physical Education by the Rio Grande do Sul Federal University. Currently on the Master Degree Course on Human Movement Sciences in the Rio Grande do Sul Federal University.
2. Graduated in Physical Education by the Rio Grande do Sul Federal University.
3. Pediatric Physician. Professor at the Physical Education School from the Rio Grande do Sul Federal University. Doctorate Degree from the McMaster University, Canadá.

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Correspondence to:
Patrícia Schneider
Rua Felizardo, 750, Jardim Botânico
90690-200 – Porto Alegre, RS
E-mail: schneiderpatricia@yahoo.com.br

strength measure such as movement speed, articular angle and the environmental conditions. The control of these factors is important due to the specificity of the sportive movement, being controlled in laboratory with the use of computational dynamometers in order to evaluate the different types of strength (isometric and isokinetic). The applicability of the *Cybex Norm* measure in the sportive performance field, health and rehabilitation may present some advantages such as to test different types of strength (isometric and isokinetic). Despite the high cost, this equipment is already used at the main exercise laboratories for extended use in different groups(12).

The specific speed of the competitive volleyball movements has guided the development of isokinetic training programs addressed for the production of muscular contraction at specific speed at both muscular and neural levels, reason why the isokinetic muscular strength measuring appears to be so important.

Systematic studies using computational isokinetic dynamometers on the strength evaluation in children and youth volleyball athletes are unknown. The first objective of this study was to describe and to compare the muscular strength (isometric and isokinetic) with the use of the computational dynamometry in healthy children and youth volleyball athletes, from both genders at different maturational degrees.

MATERIAL AND METHODS

Design

The descriptive and transversal study evaluated the muscular strength in children and youth volleyball athletes from both genders, divided into three groups according to the maturational degree.

Sample

The sample was composed of children and youth from both genders and volleyball athletes in a competitive sportive training from a sports club.

66 volunteers participated on this study: 37 boys and 29 girls. The table 1 shows the sampling size and the physical characteristics of age, body mass, size, body mass index, body fatness percentile, triceps cutaneous skinfold, subscapula, suprailiac, abdomen and thigh, and thigh and arm circumference of each group. All white (except for two black) healthy individuals participated on the competitive sportive volleyball training, according to anamnesis supervised by pediatric physician(13).

The prepubescent (PP) participants trained about 4.5 weekly hours for at least one year; the pubescent (PU) trained about 7.7 weekly hours with 1-3 years of training and the postpubescent (PO) trained about 12 weekly hours with 2-6 years of training. All participated on physical education classes in school, twice a week.

As inclusion criterion, the athletes could not present any preceding muscular disease, chronic disease or obesity, being expected to cooperate with the procedures. No volunteer was excluded.

Procedures

An invitation was sent to the coaches with the purpose of informing the objectives of this study and the coaches in turn indicated the telephone number of the athletes interested in participating on this study. Their parents were contacted for elucidation and for tests scheduling. Only those who agreed with all study procedures participated in this study after their parents signed up an approval written form. The project was approved by the Research Ethics Committee from the Rio Grande do Sul Federal University. Each evaluation was performed by the same investigator for a better standardization and tests controlling. Each athlete attended once the Exercise Research Laboratory (Lapex) accompanied by one parent for the following procedures: 1) selection and elucidation; 2) maturity and body composition evaluations; and 3) strength evaluation.

The participants were self-evaluated for PP, PU and PO degrees of maturation, according to the maturational classification of Tanner (1962)(14). One female appraiser explained the self-evaluation for the girls and a male appraiser, for the boys. This self-evaluation has shown to be valid, strongly correlating with the direct observation(15).

The body mass and the size were measured in electronic balance and estadiometer label *Filizola*, and the body mass index (IMC) was calculated. The fatness percentile was calculated by means of the Slaughter *et al.* (1988)(16) equation in which parameters such as gender, race and maturational degree are taken into consideration. In order to evaluate the fatness, the cutaneous skinfold was measured always on the right side, with the use of the Lange compass and following the Lohman *et al.* (1991)(17) standards. The arm and thigh circumference (medial) were measured with the *Lufkin* metric tape.

The isokinetic (concentric) and isometric strengths were evaluated in a computational dynamometer (*Cybex Norm*), always calibrated before the beginning of tests. The movements performed were the knee extension (EJ) and the elbow flexion (FC), using the torque peak as measure.

For all participants tested, for both knee extension and elbow flexion, there was a familiarization with three movements for each speed; and after a 30-second rest, the testing started.

For the EJ measure, the individuals remained comfortably seated at the equipment's chair, holding the side support. Their backs were rested against the back of the chair, which was adjusted for the fossa poplitea to be rested on the anterior part of the seat and for the central point of the knee articulation to be aligned to the dynamometer rotation axis. The hands were holding the side support. For a better thigh fixation, a belt was fastened above the knee articulation such as a seat belt in order to adjust trunk to the back of the chair.

For the FC measure, the individuals remained at decumbent position with knees bent and feet rested on a specific support. The trunk was fixed with a seat belt and the left hand holding the side of the equipment. The center of the elbow articulation was aligned to the dynamometer rotation axis. The shoulder was fixed with a belt, fastened diagonally from the right shoulder to the left elbow. This belt was fixed to the equipment with the objective of minimizing the movement and avoiding the compensation with the shoulder musculature.

Firstly, the isokinetic strength was evaluated at speeds of 60 and $90^{o}.s^{-1}$, with three replicates for each speed with a 90-minute interval between them. The strength highest peak was considered as result.

After 120 seconds, the isometric strength was evaluated at angles of 45 and 60° of EJ (total extension = 0^{o}) and 60 and 90^{o} of FC (total flexion = 180^{o}), always in this order and at the right side, with a 120-second interval between

TABLE 1
Physical characteristics of sampled children and youth (mean ± standard deviation)

		Prepubescent	Pubescent	Postpubescent
Sample size	Boys	10	15	12
	Girls	11	13	5
Age (years)	Boys	10.2 ± 0.8	12.5 ± 2.0	17.0 ± 1.1
	Girls	10.2 ± 1.1	12.2 ± 1.4	16.8 ± 1.5
Body mass (kg)	Boys	45.6 ± 11.2[b]	53.8 ± 12.0[b]	76.9 ± 9.6
	Girls	40.7 ± 9.3[ab]	57.4 ± 10.3	67.6 ± 6.2
Size (cm)	Boys	150.3 ± 0.09[ab]	165.5 ± 0.12[b]	188.2 ± 0.05*
	Girls	147.6 ± 0.11[ab]	163.0 ± 0.06[b]	178.2 ± 0.04
IMC (kg/m²)	Boys	20.0 ± 3.1	19.4 ± 2.3	21.7 ± 2.7
	Girls	18.5 ± 2.1[a]	21.7 ± 3.5	21.3 ± 1.5
% of Fatness (Slaughter, 1988)	Boys	25.4 ± 5.7[b]	21.4 ± 4.6*	20.1 ± 2.5*
	Girls	22.3 ± 5.1	28.7 ± 7.6	24.8 ± 3.5
Triceps (mm)	Boys	15.5 ± 3.8[b]	12.5 ± 4.7*	8.9 ± 2.7*
	Girls	14.9 ± 5.4	20.4 ± 6.8	16.4 ± 3.8
Subscapula (mm)	Boys	12.8 ± 6.3	9.1 ± 4.3*	10.1 ± 2.7
	Girls	8.9 ± 4.4[a]	16.0 ± 6.1	12.3 ± 2.5
Suprailiac (mm)	Boys	17.6 ± 10.1	13.4 ± 7.7*	10.0 ± 4.4*
	Girls	15.2 ± 6.6	20.9 ± 7.9	16.6 ± 4.3
Abdomen (mm)	Boys	21.0 ± 10.4[b]	15.0 ± 7.7*	10.6 ± 4.9*
	Girls	14.9 ± 6.6[a]	23.9 ± 6.3	21.4 ± 4.8
Thigh (mm)	Boys	22.2 ± 6.7[b]	17.4 ± 4.6c*	10.6 ± 3.2*
	Girls	20.6 ± 5.7	23.3 ± 6.8	21.0 ± 2.5
Arm circumference (cm)	Boys	23.3 ± 2.6[b]	24.0 ± 2.1[b]	28.6 ± 1.9
	Girls	22.2 ± 2.5[ab]	25.7 ± 2.6	27.0 ± 1.3
Thigh circumference (cm)	Boys	45.3 ± 4.5[b]	47.5 ± 5.2[b]	54.4 ± 4.2
	Girls	42.9 ± 4.8[ab]	50.2 ± 6.1	54.1 ± 2.2

* Different from girls for the same maturational degree ($p < 0.05$).
[a] Different from PU; [b] Different from PO.

them. The test was composed of three maximal voluntary contractions at each angle, each one with a contraction time of five seconds, with a 90-second interval between them, considering that the contraction time in order to assure that the maximal strength has been reached is between three and five seconds with two up to five contractions[18]. The interval was of 120 seconds between the angles. The torque highest peak from the three attempts was considered as result.

The rest interval protocol used was based on the work of Ramsay *et al.*[19] and Hebestreit *et al.*[20] During all evaluations, the same appraiser performed a verbal stimulus. At the end of the tests, the appraisers guided the elongation of the tested musculature.

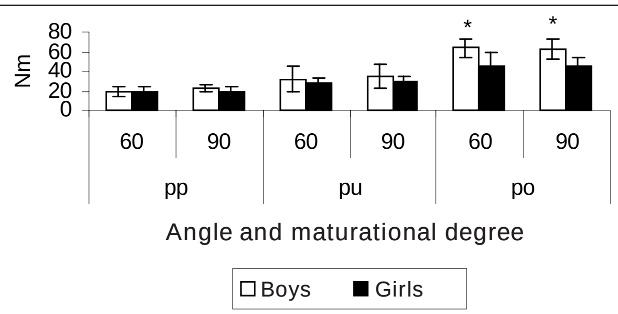
Statistical analysis

The results are expressed in terms of the average and standard deviation per group, according to maturation and gender. The analysis of variance (ANOVA) was used for the comparisons between gender and maturational degree. To investigate where significant differences between the maturational degrees occurred, the *post hoc* Tuckey test was used. The significance level considered was $p < 0.05$. The program SPSS 8.0 software was used for the analyses.

RESULTS

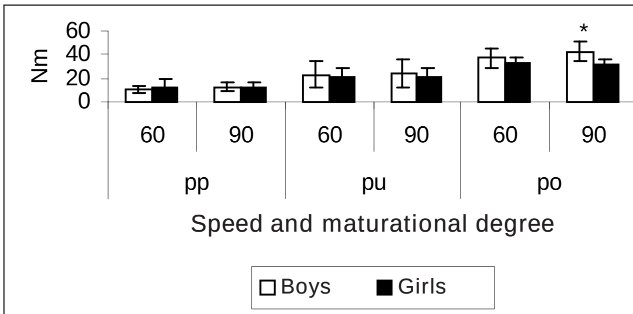
The figure 1 shows the results of the FC isometric strength per gender and maturation. In the isometric strength, boys were stronger than girls only for group PO, for both angles. The figure 2 shows the results of the FC isokinetic strength per gender and maturation. In the isokinetic strength, boys were stronger than girls only for group PO and at speed of $90^{o}.s^{-1}$. In both the FC isometric and isokinetic strengths, the older groups were always stronger than the younger ones, for both genders.

The figure 3 shows the results of the EJ isometric strength per gender and maturation. Boys and girls presented similar results in the isometric strength tests, regardless the maturational degree. Figure 4 shows the result of the EJ



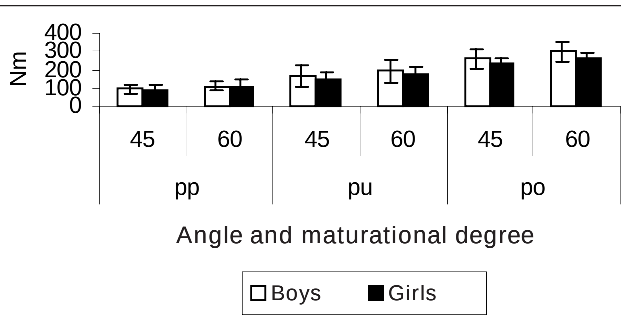
* p < 0.05 in relation to girls
Pre-pubertal (PP) were different from pubertal (PU) and from post-pubertal (PO) and PU were different from PO, among the same gender (p < 0.05).

Fig. 1 *– Elbow flexion (EF) isometric muscular strength in Nm (average ± standard deviation)*



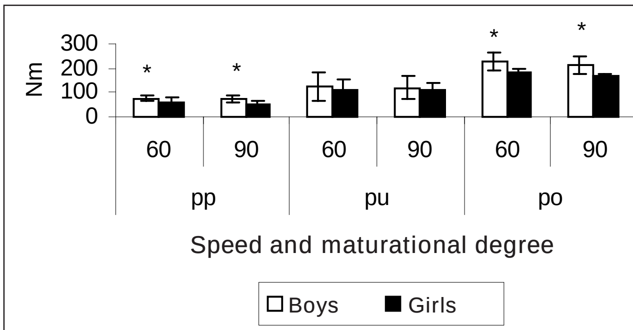
* p < 0.05 in relation to girls
Pre-pubertal (PP) were different from pubertal (PU) and from post-pubertal (PO) and PU were different from PO, among the same gender (p < 0.05).

Fig. 2 *– Elbow flexion (EF) isokinetic muscular strength in Nm (average ± standard deviation)*



* p < 0.05 in relation to girls
Pre-pubertal (PP) were different from pubertal (PU) and from post-pubertal (PO) and PU were different from PO, among the same gender (p < 0.05).

Fig. 3 *– Knee extension (KE) isometric muscular strength in Nm (average ± standard deviation)*



* p < 0.05 in relation to girls
Pre-pubertal (PP) were different from pubertal (PU) and from post-pubertal (PO) and PU were different from PO, among the same gender (p < 0.05).

Fig. 4 *– Knee extension (KE) isokinetic muscular strength in Nm (average ± standard deviation)* isokinetic strength by gender and maturational degree. In the isokinetic strength, boys were stronger than girls for groups PP and PO at both speeds tested (60 and 90°.s^{-1}). For both isometric and isokinetic strengths, the older groups were always stronger than the younger ones, for both genders.

DISCUSSION

The present study described and compared the muscular strength of boys and girls volleyball athletes from nine to 18 years of age. FC and EJ tests were performed in an isokinetic dynamometer, using a protocol previously applied to groups of non-athletes children and youth[12].

We believe that the sample was representative of a competitive volleyball athlete children and youth group. No difference statistically significant was found in the body mass, size and IMC (table 1) between genders, except for size in the group PO in which boys were taller than girls. With regard to the fatness, the girls demonstrated higher values of cutaneous skinfold and fatness percentile than boys from puberty, except for the subscapula in the group PO. This differences standard seems not to be affected by the practice of the physical activity, once it also occur in non-athletes[21]. Furthermore, part of the difference may be due to the high calorie ingestion, as demonstrated by studies by Almeida and Soares[2], when studied a group of female volleyball athletes from Rio de Janeiro with training load equal to the present study and average age of 16 years.

Coincidently, our PO athletes presented anthropometric values quite similar to the mentioned study (body mass of 64.35 kg; size of 1.74 m; fatness percentile of 20.51; triceps of 17.55 mm; subscapula of 13.74 mm; suprailiac of 12.95 mm; abdomen of 21.01 mm; thigh of 26.05; arm perimeter of 26.01 cm and thigh perimeter of 52.29 cm).

With regard to the muscular strength, according to results, the study has emphasized that the maturational degree strongly influences the muscular strength, and differences statistically significant were found for all groups tested for both genders.

With regard to the prepubescent groups, the boys were stronger than the girls only for the EJ isokinetic test at 60°.s^{-1}. In a study by Schneider *et al.*[12], who used the same protocol as the present study with a non-athletes sample, it is observed that the boys from group PP were stronger than the girls for the EJ isometric tests at 45 and 60°, and for the FC isokinetic tests at 60 and 90°.s^{-1}. This indicates that the girls from group PP of this study, who practice volleyball competitively, reach strength levels similar to boys, especially at the upper members. This finding is supported by studies[22,23] that demonstrated responses of strength increase on prepubescent girls after strength training.

In the present study, no difference was found between genders in none of the tests between the pubescent groups. In the study[12] with non-athletes pubescent previously mentioned, the boys were stronger than the girls in most of the tests. This may demonstrate that the pubescent girls, who participate on a competitive sport modality such as volleyball, may increase their strength in order to become as strong as the boys. It may be discussable how much of this strength is due to the volleyball specific training, but anyhow, these results reveal the importance of the sportive practice, especially among female youth, who belong to a risk group for the decrease of the physical activity degree[24].

In the postpubescent groups, more differences were found between genders, comparing to the prepubescent and pubescent groups. In this case, boys were significantly stronger than girls in three out of the four FC tests and in two out of the four EJ tests. For the other tests, despite the higher torque peak values presented by boys, the difference was not statistically significant.

It is possible that the differences between genders were even higher if a higher number of girls had participated in this study. This was not possible due to the non-attendance of girls on tests, despite the facilities for the scheduling of them.

The highest strength of the male PO may be explained due to the increase on the muscular mass in this gender and age range. The differences between genders occurred, despite the similar physical trainings. However, these strength differences between genders may be diminished in the upper members if corrected by the muscular mass, and may not exist in the lower members[25]. During the growth peak, the boys tend to increase the difference of strength gain in relation to the girls[21]. With the beginning of puberty, the strength increase may be different between genders by the testosterone androgenic action[4]. Even not quite strong as the boys, the girls from the present study presented values about 100% higher than values from a similar group of non-athlete girls[12], indicating that the volleyball practice led to an increase on the muscular strength.

Despite the general increase on the muscular strength found in the present study in relation to the non-athletes, this increase could be even optimized if the athletes participated on a specific training of muscular strength. In the study of Smith *et al.*[7], volleyball athletes were divided into strength-training group and control group. The strength-training group increased significantly the vertical jump and the knee extension at 180°.s^{-1}, while the control group did not obtain significant increase, otherwise decreasing the power of the block jump. This jump power decrease was positively correlated to the decrease on the knee extension strength at 180°.s^{-1}. The authors suggested that this performance decrease might have occurred due to the lack of strength training, thus leading to a higher fatigue in this muscular group.

In the present study, we did not correlate the results of muscular strength to tests of volleyball performance. We attempted to standardize the evaluation protocol based on a previous study[12] in order to enable comparisons between groups. We understand that we could include other movements, angles and speeds that would reflect other game situations and thus, to correlate them to the sport performance. Anyway, the protocol used in laboratory with dynamometry allowed the control of variables that could affect the strength values, enabling higher accuracy on the selected tests.

Finally, we believe that these data reflect the FC and EJ isometric and isokinetic strengths in a sample composed of boys and girls volleyball players from different maturational degrees. We have found that boys from PO, in general, were stronger than girls, and it was clear that the older groups were the strongest. These data could serve as reference for other groups of volleyball athletes.

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