# Development and validation of a new system for talent selection in female artistic gymnastics: the PDGO Battery*

Patrícia Arruda de Albuquerque[1] and Paulo de Tarso Veras Farinatti[2]


## ABSTRACT

The artistic gymnastics (AG) is based on a wide range of motor activities that require specific capacities. However, tests to detect the potential for its excellence in early ages are still lacking. The purpose of the present study was to develop a test for talent selection in female artistic gymnastics. The activities used by Brazilian specialists were investigated by questionnaire and the international literature was reviewed. The 30 mentioned activities were compiled in a 22-test battery that was applied in 55 children of 5 to 9 years-old. Results obtained were treated by principal component factor analysis. Individual factor scores were extracted from the first factor, which were adopted as an indicator of the performance potential in artistic gymnastics (PPAG). At last, a stepwise multiple regression was calculated, using the factor scores as independent variable, producing an equation with eight activities to estimate PPAG. Construct validity, cross validity and reliability of the equation were tested. Sixteen experienced gymnasts and 19 apprentices were tested for cross validation. Mean PPAG found for the gymnasts (85.11) was significantly higher than data for the apprentices (54.80), indicating that the battery can discriminate the performance potential. Construct validity was confirmed by exploratory factor analysis, suggesting that the activities were related to a similar dimension of motor performance. Inter- and intra-observers reliability was tested by linear correlation and Student *t* test. The correlation values ranged between 0.83 and 1.00 ($p < 0.05$). No differences were detected between the means in all test situations. In conclusion, the application of the proposed battery revealed to be fast and simple, as well associated with low cost and easy understanding. Furthermore, data suggested that it has good validity and reproducibility, authorizing its application in initial talent selection for AG. However, additional studies should be conducted to confirm these results, including more important samples and longitudinal approaches, in order to verify the predictive validity of the method.


**Keywords:** Training. Sport. Children. Gymnastics. Evaluation. Sports talent. Physical fitness.

## INTRODUCTION

Artistic Gymnastics (AG) includes a wide range of motor activities which demand specific abilities from the part of its practitioners. It is a sport whose gestures depend on techniques which due to high normative standards require particular and, at a certain extent, unusual physical characteristics. For that reason, it is important to perform a previous talent selection so that the work can be differently focused for children who intend to reach elite performance and the ones who will practice it as leisure. An aspect is usually neglected when one talks about talent selection – actually, not only does this process help in the identification of athletic potential of future athletes, but also suits the work to those who do not have it, avoiding hence, overloads in children who could be practicing the sport without competitive aims. In other words, the talent selection makes it easier to perform the *'right work with the right person'*.

With this grounding, the performance of a tests battery which verifies such abilities is considered important in the talent selection process for AG. On the other hand, the existing ways for talent selection for Artistic Gymnastics are empirical and lack scientific evaluation seriousness. Hernández[1] confirms it when affirms that there are three recognized ways to select talents: observation of school competitions by coaches; indication from the physical education teacher and observation of social activities. The author does not oppose to the fact that these selection ways are applied within a system; however, he considers important the inclusion of others which have more scientific support, reach from a grounding of wide application and would be supported by physical value tests or motor performance, allowing thus, an improvement in the proficiency of selection and detection of youngsters for this sport.

AG is within the 'technically complex' sports, being characterized by the expression of motor activities, complexity of exercises coordination and high demands of stability during its performance. As illustration, Filin and Volkov[2] state that some gymnasts from different age groups have relative strength flexibility indices similar to the ones presented by champions of this modality. One may say from this fact that it would be interesting to obtain data about these variables from early phases of training. In other words, there is support for the evaluation of motor-physical aspects as remarkable aspects in the initial phase of a talent selection process.

In Brazil, a process supported in research with the aim to organize own methods sufficiently experienced in practice needs to be initiated, since the material about this modality is reduced and insufficient. Moreover, it is difficult to access what is produced by other countries. Extremely high level of competitions, high technical and physical specificity demanded from gymnasts and lack of scientific data about tests which detect these specificities, show the need to have more objective evaluation systems which enable the identification of children with specific talent for AG. Therefore, this study has the aim to propose and raise evidence for validation of a motor-physical test battery designed to the selection of talents for Women's Artistic Gymnastics.

## METHODOLOGY

### Sample

The main sample was composed of 55 girls who practiced or not Artistic Gymnastics, being born between 1994 (9 years old)


* Laboratório de Atividade Física e Promoção da Saúde, Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro.

1. Laboratório de Atividade Física e Promoção da Saúde, Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro, e Mestrado em Educação Física, Universidade Gama Filho.
2. Laboratório de Atividade Física e Promoção da Saúde, Instituto de Educação Física e Desportos, Universidade do Estado do Rio de Janeiro, e Mestrado em Ciências da Atividade Física, Universidade Salgado de Oliveira.


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**Correspondence to:** Paulo de Tarso Veras Farinatti, Rua São Francisco Xavier, 524, sala 8.133-F, Maracanã – 20550-013 – Rio de Janeiro, RJ, Brasil. E-mail: farinatt@uerj.br

and 1998 (5 years old) in the year which the study was conducted, who voluntarily participated in the tests (group A). The ages were stored by the year of birth, as it is done in the official categories of AG. Boys were excluded from the study once women's and men's modalities are very different, with distinct techniques and rules. Girls born before 1994 and after 1998 were also excluded since they were not included in the optimum age group for the participation in talent selection tests, according to data found in the literature[1-3] and in the answers of the questionnaires filled out by Brazilian coaches (see section 2.2.1). The children who did not practice AG and participated in the tests were invited by banners and sound cars around the streets. The practitioners were part of AG schools from the Grajaú Country Club and Miécimo da Silva Sports Center (Rio de Janeiro, RJ). Individuals responsible for all the participants were told about the study's characteristics and provided written consent, according to recommendation by 196/96 Resolution from the National Health Staff. This study was approved by the Ethics Committee of the Institution as well.

## Methods

*Tests Battery Design Applied to the Main Sample*

Questionnaires sent to specialists in AG in Brazil were used in order to identify a profile of motor skills about which there would be a consensus concerning needs for elite performance. The questionnaire was developed in a simple and objective way, with five questions besides information on name and work place. Simplicity had the aim to decrease to the most the sample mortality in this phase of the study. The questions mentioned the categories the coaches worked with, the activities, age group, specific skills (physical characteristics) and characteristics (personality traits) desired by them in a possible test for women's AG talent selection. Moreover, the coaches were asked whether they applied tests in the institutions they worked for. The questionnaires were distributed by fax, e-mail, snail mail or in hands to the coaches in charge of the women's AG of all institutions registered in the Brazilian Gymnastics Confederation (BGC) and some more registered in the Gymnastics Federation of Rio de Janeiro State (GFRJE). Therefore, a total of 24 questionnaires were sent to the coaches responsible for the women's AG of these institutions. It is important mentioning that in some of the institutions more than one coach sent an answer and that some others did not send any answer. 25 questionnaires were returned and later used for the tests battery.

Through the answers analysis it was possible to observe that 9 coaches worked with the junior category, 16 with the pre-junior category, 17 with the youngsters category, 15 with the juvenile category and 11 with the senior category. Many of them acted in more than one category concomitantly. Concerning the fact they performed tests to select children who would join the women's team of the institutions they worked for, 17 answered positively and 8 said that they did not. The age group considered optimum for such tests was between 5 and 10 years. The physical characteristics mentioned were: strength, flexibility, balance, coordination, agility, velocity, resistance, rhythm and power. The personality traits were: courage, determination, persistence, discipline, willpower, willingness to win, competitiveness, pain tolerance, interest in AG, perseverance, dedication, goodwill, responsibility, determination *('guts')*, willingness to learn, concentration and learning capacity, intelligence, punctuality and motivation. These results are summarized in chart 1. The majority of the answers included more than one suggestion, both for age and physical characteristics as well as personality traits.

Concerning the proposed activities, 30 were suggested for application in tests with the purpose to select girls to join elite training teams. In chart 2 all mentioned activities with respective physical characteristics, personality traits and frequency they have appeared are shown.

**CHART 1**
**Ages, physical characteristics and suggested personality traits**

| Ages | n | Physical characteristics | n | Personality traits | n |
|---|---|---|---|---|---|
| 5 years old | 5 | Strength | 20 | Persistence | 16 |
| 6 years old | 14 | Flexibility | 18 | Discipline | 10 |
| 7 years old | 13 | Coordination | 15 | Courage | 9 |
| 8 years old | 7 | Power | 8 | Concentration ability | 2 |
| 9 years old | 4 | Balance | 6 | Learning ability | 2 |
| 10 years old | 2 | Agility | 6 | Competitiveness | 1 |
| | | Velocity | 4 | Pain tolerance | 1 |
| | | Rhythm | 1 | | |
| | | Resistance | 1 | | |

The answers to the questionnaires were organized in comparison with the *'Talent Opportunity Program'* (TOPs)(*) data and tests applied to the Brazilian women's AG team for the elaboration of the tests battery version which would be applied to the children in the first step (pilot study). For the present study, the activities which put the child's integrity at risk, demanded previous practice experience, had high degree of difficulty or demanded very specific skills were excluded. Moreover, some tests for repeated physical characteristics were also excluded. Thus, from the 30 initial activities, 12 were discarded. Chart 3 presents the final version of the tests battery of the pilot study, grouped according to physical characteristics in which they fit in as well as parts of the body they refer to.

Initially, 15 children participated in the pilot study, having been recruited like the main sample. Exercises 4 (hip abduction with chest flexion – seating position) and 5 (chest flexion with lower extremities united – seating position) of chart 3 were subdivided when the tests battery was applied to this group, since they provided grades only according to the performance quality, which were not sufficient for the activities' evaluation. It was then decided to include exercises 4a (hip abduction – seating position) and 5a (chest flexion with lower extremities united – standing position), measured in interval scale, so that the hip, chest and lower extremities flexibility could be more objectively evaluated. Again for this reason, in the evaluation of exercises 14 (outer set-square on the low step) and 15 (natural walk on the balance beam), it was decided not only to distribute grades according to the movements execution, but also to quantify the time each child remained performing the task.

All tests were applied at the same day and by a single evaluator. Strength and power activities were organized in rotation per muscle group to avoid children's over loading, always following the same application order: flexibility exercises, power exercises, dynamic strength and static strength alternated, dynamic balance exercises, and finally coordination exercises. Therefore, the tests were performed in the following order: 1, 2, 3, 4a, 4b, 5a, 5b, 6, 9, 13, 7, 10, 12, 8, 11, 15, 16, 17, 14 and 18.

*Development of the final tests battery*

In order to develop the final version of the tests battery, the outcomes of the tests applied in the 55 children of the main sample were statistically treated by factorial analysis of main components. The factors were defined based on a 1.0 cut for the own value (*eigen value*). From that on, individual factorial scores were calculated, as well as a step-by-step multiple regression using the factorial scores as independent variable.

The multiple regression was performed so that it would include in the final equation variables which F value for significance was higher than 1.0 and eliminating redundant variables for preview of

* Talent selection system organized by the 'USA Gymnastics', maximum organ of the AG in the United States of America. The 'TOPs' consists of an educational program and talents selection for women's gymnastics from 7 to 11 years old and their respective coaches.

**CHART 2**
**Suggested activities concerning physical characteristics and personality traits**

| Suggested activities | Approached physical characteristic | Frequency |
|---|---|---|
| 1. 20 meters run*/ | Power and velocity – Mmii | 12 |
| 2. Repeated stretched jumps (8) on the floor | Power – Mmii | 2 |
| 3. Distance jump*/ | Power – Mmii | 7 |
| 4. Vertical impulse | Power – Mmii | 1 |
| 5. Jumps in pliometry (plinto w/3 elements)* | Power – Mmii | 2 |
| 6. Elbow flexion in suspension/ | Strength – Mmss | 14 |
| 7. Rope climbing (3 meters)*/ | Strength – Mmss | 13 |
| 8. "Arms flexion on the floor"/ | Strength – Mmss | 3 |
| 9. "Dorso pull" on bar | Strength – Mmss | 2 |
| 10. Elbows flexion on the suspended rest (beam) | Strength – Mmss | 2 |
| 11. 'L' set-square in suspension at 90º (espaldar) | Static strength– chest | 9 |
| 12. Hip flexion in suspension*/ | Dynamic strength– chest | 4 |
| 13. Split with Antero-posterior opening– right lower extremity to the front*/ | Flexibility – Mmii | 12 |
| 14. Split with antero-posterior opening – left lower extremity to the front*/ | Flexibility – Mmii | 12 |
| 15. Shoulders flexibility/ | Flexibility – Mmss | 7 |
| 16. Back handspring | Flexibility – Mmss | 10 |
| 17. Hip abduction with chest flexion (in seating position) | Flexibility – hip/chest | 13 |
| 18. Chest flexion with lower extremities united | Flexibility – chest/Mmii | 6 |
| 19. Knees (extension) and feet flexibility (plantar flexion and extension) | Flexibility – Mmii | 4 |
| 20. To naturally walk on the high beam | Dynamic balance | 5 |
| 21. To perform three spins the longitudinal axis with eyes open and after to walk in a straight line with eyes closed | Dynamic balance | 2 |
| 22. Little jumps coordination with arms moving | Coordination | 2 |
| 23. Outer Set-square on the low step – Specific ability | General static strength | 3 |
| 24. Forward somersault – Specific ability | Coordination | 2 |
| 25. Run (approx. 15 meters) and jump for a plinto of three elements – specific ability | Velocity/power-Mmii | 1 |
| 26. Swing on bar with hands switch (1/2 roll) – Specific ability | Agility | 1 |
| 27. Walkover – Specific ability | Coordination | 1 |
| 28. Handspring on the wall – Specific ability | Balance and coordination | 2 |
| | **Personality treats** | |
| 29. Jump from the low to the high bar of the uneven bars ending in suspension | Courage | 1 |
| 30. Jump from the high bar of the uneven bars to the mat | Courage | 1 |

* tests used by the permanent Brazilian team Mmii – lower extremities; / tests from the 'TOPs' (Talent Opportunity Program, EUA); Mmss – upper extremities.

**CHART 3**
**Final version of tests battery**

| Physical skills | Body parts | Activity |
|---|---|---|
| Flexibility | Mmii | 1. Split with antero-posterior opening – right lower extremity<br>2. Split with antero-posterior opening – left lower extremity |
| | Mmss | 3. Shoulders active flexibility |
| | Hip and chest | 4a. Hip abduction – seating*<br>4b. Hip abduction with chest flexion – seating position |
| | Chest and Mmii | 5a. Chest flexion with lower extremities united – standing*<br>5b. Chest flexion with lower extremities united – seating |
| Power | Mmii | 6. 20-meter run<br>7. Repeated extended jumps on the floor (8)<br>8. Distance jumps |
| Dynamic strength | Mmss | 9. Elbow flexion in suspension<br>10. Rope climbing – three meters<br>11. 'Arm flexion on the floor' |
| | Chest | 12. Hip flexion in suspension |
| Static strength | Chest | 13. 'L' set-square in suspension at 90º (espaldar) |
| | General | 14. Outer set-square on the low step |
| Dynamic balance | | 15. To naturally walk on the high beam<br>16. To perform three turns on the longitudinal axis with eyes open and later to walk in a straight line with eyes closed |
| Coordination | | 17. Coordination of little jumps with arms movements<br>18. Front somersault |

* Activities included after the pilot study; Mmii – lower extremities; Mmss – upper extremities.

factorial scores in a p level < 0.05. Finally, it was identified which of the 22 activities would better represent the global performance in all tests, reaching to a battery with a sensibly lower amount of activities. All procedures were performed with the aid of the Statistica® 6.0 software (Statsoft, USA).

The following strategies were completed for validation of the tests battery developed, named Performance Potential in Artistic Gymnastics Battery (PPAG Battery):

a) Battery application in an inexperienced group composed of 19 beginning children from the AG schools of the Health Clubs *Body Planet*, *Akxe* and from the *Grajaú Country Club*, as well as in a group of 16 AG athletes, composed by the best Brazilian gymnasts(**) from the same age group (9 to 15 years old). Thus, the describing potential of the battery was tried to be determined along with its crossed validity level. After having the crossed validity between the two groups verified (school and gymnasts), the correlation between the final score and age within each group was performed.

b) Checking of the reproducibility of the battery, inter-observers trustworthiness (simultaneous application) and intra-observer trustworthiness (successive measurements). In order to verify the inter-observers trustworthiness, the tests of the final battery were

** Ginastas que conquistaram as melhores colocações nos campeonatos brasileiros de 2003 nas seguintes categorias: pré-infantil B e A (9 e 10 anos), infantil B e A (11 e 12 anos) e uma ginasta da categoria juvenil. É importante ressaltar que algumas delas já competiram em categorias superiores às suas (categoria II) e obtiveram as primeiras colocações. Vale lembrar que uma das ginastas testadas não participou das competições, pois estava contundida.

applied in a group of 16 children. In order to verify the intra-observers trustworthiness, a group of 5 children repeated the test on the following day and another group of 6 children repeated the test with a four-day interval, having all been evaluated by the same observer. In all cases, the correlation levels (r of Pearson) as well as the difference between means (paired t-Student test), for a significance level of $p < 0.05$ were appreciated.

c) Validity checking of the battery structure through confirmation factorial analysis.

The study's complete flowchart is presented in figure 1.

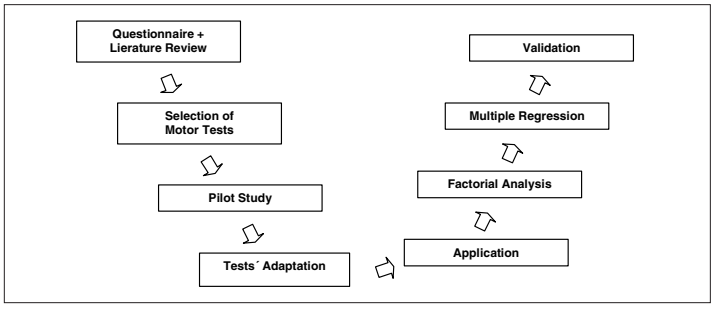


***Figure 1*** *– Study's complete flowchart*

## RESULTS

### Development of the final version of the tests battery

After the pilot study, 22 tests were applied to the main sample. The outcomes of the performed tests were introduced in an analysis of main components, with the purpose to identify the most representative factors of the total variance of the tests. However, the normality of its distribution by the analysis of asymmetry and kurtosis coefficients was verified (between –0.5 and 0.5), of the Kolmogorov-Smirnov test ($p > 0.05$) through the *'normal-plot'* strategy (scores z x buildups). The distribution was accepted as normal if it satisfied two of these three criteria. The results showed acceptable levels of normality for all performed tests.

The factorial analysis began by the calculation of the correlations matrix between physical-motor tests. This matrix was submitted to extraction of main components, followed by *varimax* rotation (table 1). Five factors were selected for interpretation of the ratios between motor tasks applied (eigen values > 1.0). The first factor (eigen value = 9.41) concentrated a significantly higher proportion of the variance of the entrance variables: from a total of 70.21% of the total variance explained by the solution found, 42.80% came from the first factor. Moreover, the *eigen* value of the main factor, was around five times stronger than the second factor.

**TABLE 1**
***Factor Loadings* (varimax) – analysis of main components**

| Variable | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 |
|---|---|---|---|---|---|
| EX1Teste | –0.75 | –.030 | 0.25 | –0.21 | 0.07 |
| EX2 | –0.80 | –0.34 | 0.24 | –0.08 | –0.03 |
| EX3 | 0.50 | 0.13 | 0.40 | –0.27 | 0.20 |
| EX4A | 0.61 | 0.56 | 0.10 | 0.14 | –0.15 |
| EX4B | 0.68 | 0.56 | 0.10 | 0.14 | –0.14 |
| EX5A | 0.79 | 0.27 | –0.15 | –0.07 | 0.21 |
| EX5B | 0.67 | 0.24 | –0.04 | 0.27 | 0.40 |
| EX6 | –0.72 | 0.24 | –0.43 | 0.17 | 0.21 |
| EX7 | 0.60 | –0.18 | 0.35 | 0.05 | –0.03 |
| EX8 | 0.84 | –0.12 | 0.25 | –0.04 | 0.02 |
| EX9 | 0.59 | –0.48 | –0.26 | –0.10 | 0.26 |
| EX10 | 0.78 | –0.06 | 0.20 | –0.27 | –0.15 |
| EX11 | 0.76 | –0.41 | –0.17 | –0.08 | 0.12 |
| EX12 | 0.79 | –0.37 | –0.23 | 0.00 | 0.09 |
| EX13 | 0.66 | –0.31 | –0.42 | 0.07 | 0.03 |
| EX14A | 0.71 | –0.03 | –0.03 | –0.05 | –0.12 |
| EX14B | 0.73 | 0.00 | –0.37 | –0.02 | –0.24 |
| EX15A | 0.41 | 0.03 | 0.19 | –0.43 | 0.27 |
| EX15B | 0.53 | –0.26 | 0.24 | 0.51 | –0.39 |
| EX16 | 0.08 | 0.14 | –0.39 | –0.51 | –0.59 |
| EX17 | 0.24 | 0.25 | 0.12 | –0.55 | 0.00 |
| EX18 | 0.60 | –0.06 | 0.37 | 0.26 | –0.16 |
| Eigen value | 9.41 | 1.87 | 1.60 | 1.45 | 1.10 |
| % accumulated variance | 42.80 | 51.31 | 58.59 | 65.21 | 70.21 |

The next step consisted of the calculation of the factorial scores associated with the main component. A score type $\Sigma a_i x_i$, was attributed to each individual, where $a_i$ corresponded to the saturation of the first component and $x_i$ to each of the results of the motor-physical tests. However, it was needed to find a way to represent these scores from the origin variables, through a regression equation. Therefore, a progressive step-by-step multiple regression (*stepwise forward*) was calculated, in which the factorial scores were the dependent variable and the tests performed composed the independent variables. The summary of the outcomes of the multiple regression among the factorial scores and the motor-physical tests are shown in table 2. Note that the equation has an excellent degree of adjustment to the values of the independent variable.

**TABLE 2**
**Summary of the multiple regression between factorial scores and motor-physical tests (n = 55)**

| N = 55 | Beta | Beta ESE | B | B ESE | t(44) | p |
|---|---|---|---|---|---|---|
| Intercepto | | | –0.270 | 0.645 | –0.425 | 0.673 |
| EX8 | 0.182 | 0.046 | 0.006 | 0.002 | 3.236 | 0.002 |
| EX1 | –0.149 | 0.046 | –0.032 | 0.010 | –3.231 | 0.002 |
| EX12 | 0.139 | 0.053 | 0.015 | 0.006 | 2.627 | 0.012 |
| EX2 | –0.129 | 0.055 | –0.025 | 0.011 | –2.342 | 0.023 |
| EX10 | 0.125 | 0.046 | 0.093 | 0.035 | 2.702 | 0.009 |
| EX11 | 0.151 | 0.048 | 0.024 | 0.008 | 3.141 | 0.003 |
| EX5A | 0.154 | 0.049 | 0.025 | 0.008 | 3.162 | 0.003 |
| EX14A | 0.080 | 0.037 | 0.014 | 0.007 | 2.13 | 0.039 |

Dependent variable: factorial scores $F(10.44) = 137.15$; $p < 0.0001$; $r = 0.98$; $r2 = 0.97$; estimated standard error (ESE) = 0.19.

The coefficients of the B and Beta regression are highly significant and the t values for a freedom degree of 44, confirmed the validity of the model. It is observed that the intercept is significantly different from 0, and that the B and Beta coefficients are all different among them ($p < 0.001$). The data provided by the B and Beta coefficients are essentially the same. Nevertheless, these latter are calculated after a standardization of all variables, with mean 0 and standard deviation of 1. Thus, the magnitude of the Beta coefficients allows the comparison of the relative distribution of each independent variable to the final equation. As evident in our model, the contribution of the variables included was balanced. The regression then allowed the inclusion in the statistical model only the tests which significantly contributed, with no redundancy, with the preview of the factorial scores. From a total of 22 initial tests, a model of equation which included only the eight ones presented in table 2 was reached.

Later, the raw scores calculated by the regression equation were changed into a standard unit, according to the mean and standard deviation of the observed population. This procedure was necessary so that it was possible to compare the final score among the most talented individuals. The creation of standard-scores is usual in studies which compare greatnesses of different nature. Usually, one takes as starting point the definition of z scores for the entire standardization. Thomas and Nelson[4] mention yet the T scores, which correct the z scores for a mean of 50 and standard deviation of 10 (T score = z score x 10 + 50). This action facilitates data interpretation, since negative and decimal values are eliminated (for instance, a z score of –1.00 equals a T score of 40). Since the

factorial scores are characterized for having mean and standard deviation similar to the one observed in the z scores, in order to reach to the final system of the tests battery rating proposed, the procedure previously described was sufficient. The raw equation generated by the regression model as well as that transformed by the T scores, are presented in chart 4.

**CHART 4**
**Equation for calculation of the final score of the motor-physical tests battery for talents selection in women's artistic gymnastics (PPAG battery)**

Final score (PPAG) = 10 x raw score + 50

where raw score =
–0.27 + 0.006 (DIST) – 0.032 (RSPLIT) + 0.015 (HIPFLEX) – 0.025 (LSPLIT) +
+ 0.093 (ROPE) + 0.024 (ARMFLEX) + 0.025 (CHFLEX) + 0.014 (SET-SQ)

Final Score = Performance Potential in Artistic Gymnastics (PPAG)
DIST – distance jump (horizontal impulse)
RSPLIT – split with antero-posterior opening of the right lower extremity
HIPFLEX –hip flexion in suspension
LSPLIT – split with antero-posterior opening of the left lower extremity
ROPE – rope climbing (3 meters)
ARMFLEX – 'arm flexion on the floor'
CHFLEX – chest flexion with lower extremities united
SET-SQ – outer set-square on the low step

### Crossed validity and trustworthiness

The outcome of the comparisons between groups (school and gymnasts) may be seen in table 3 and the correlation of the final score (PPAG) with the ages of the tested children within each group are in table 4.

**TABLE 3**
**Results of the comparisons between groups (t-Student test)**

| Group | N | Mean of PPAG | *Standard deviation* | Minimum | Maximum |
|---|---|---|---|---|---|
| School | 19 | 54.8 | 7.6 | 40.1 | 71.6 |
| Gymnasts | 16 | 85.1* | 6.9 | 74.4 | 98.8 |

* $p < 0.001$ for means between the two groups (*t test*).

**TABLE 4**
**PPAG relationship with age for each group – Correlation degree**

| Age | PPAG mean of the school students (n = 19) | PPAG mean of gymnasts (n = 16) |
|---|---|---|
| 9 and 9.5 | 52.3 | 80.5 |
| 10 and 10.5 | 54.0 | 82.7 |
| 11 and 11.5 | 55.1 | 86.0 |
| 12 and 12.5 | 59.7 | 92.2 |
| 15 | | 95.4 |
| Correlation | 0.33 NS | 0.72* |

NS – Non-significant
* $p < 0.05$

Significant differences were not observed by the t-Student test in the inter-observers trustworthiness check in the final battery exercises as well as in the final score (PPAG). The Pearson correlation for inter-observers trustworthiness for the exercises and final score was of 1.00 ($p < 0.05$), while for the intra-observers comparison the r varied between 0.83 and 1.00 ($p < 0.05$). It is important to verify that for the PPAG, the intra-observers correlation was of 0.99 ($p < 0.05$).

## DISCUSSION

We chose to divide the discussion in three steps with the purpose to give it a logical sequence. The aspects concerning the method's limitations are initially discussed. Later, the aspects of the developed selection tests battery validation are analyzed. Finally, some general aspects, including the comparison of the tests battery with other existing ones, its security, applicability and future perspectives are discussed.

It is important that the validity and reproducibility of a measurement instrument are established so that it can be applied[4-6]. Despite the effort to be careful to exclude aspects which could put these characteristics at risk, some limitations will always exist. In the case of the tests battery proposed, the number of subjects could be larger to increase the evidences of its validity. It is known that multivariate statistical techniques are more sensitive in samples whose quantitative is many times higher than the quantity of variables of exposition[5].

Other aspects to be considered are concerned with the lack of control over the degree of motivation of each child to perform the tests. Although all of them have been encouraged to perform their best, one cannot guarantee that the degree of motivation has been the maximal in all evaluated children. The effect of possible influence of the time of the day over the strength and flexibility tests performance, which could play some influence in the obtained results, was not controlled. The same can be said about the standardization of specific warm-up anteceding the test's application.

The majority of the validation studies of an instrument begin by the verification of the content's validation. A process widely used for this aim is the resource to specialists' opinion[5], which values the way through which the tests have been selected[7]. There is no information of any other investigation conducted with AG coaches in Brazil concerning their strategies for talent selection. Concerning the motor-physical tests battery for women's AG validation here proposed, specialists in AG from around Brazil working in the many existing categories in elite AG have answered the questionnaires. Therefore, the validity of the final tests battery is reinforced, which aims to express the Potential for Performance in Artistic Gymnastics (PPAG).

Once the PPAG cannot be directly measured, it was necessary to establish the construct validity of the final tests battery, using the most used statistical methods in order to establish such validity: the factorial analysis[8]. Such procedure allows that a non-observational factor (here the PPAG) is identified from a group of observable variables (the tests). In this case, the concentration of variance in the first factor was similar to the one reported by other studies which had the aim to define the simple scores from multiple variables, or the determination of main factors associated with ordinary aspects among the entrance variables[9-13]. Thus, it was considered that the saturations of the first component could be used for the calculation of an index representative of the general behavior of the set of tests applied. Finally, it was observed that the first factor undoubtfully concentrated the greatest part of the tests with factorial weight above 0.60, cutting point adopted for the definition of the connection force between a test and a given factor. Indeed, the concentration was so strong that it would make one think that the tests battery tended to refer to a single dimension of physical skill. Thinking that the tests were selected based on a hypothetical relation with the performance potential in AG; this fact was positively faced, as a possible indicator of the construct validity of the battery.

Still with the purpose to have more evidence of the final tests battery raised here represented, and especially to verify its potential of generalization, a crossed validation was performed. Based on the outcomes obtained in this validation, it could be observed that the gymnasts obtained means significantly higher ($p < 0.001$) for the final score (85.11) than the girls from the school (54.80). Actually, the highest outcome reached by the less experienced girls (71.57) was lower than the lowest value obtained by the gymnasts (74.36). This situation seems to indicate that the battery discriminates well the potential for performance in AG, showing evidence to its construct and content validity.

The fact that the final score correlation (PPAG) with age was not significant for the girls from the school (r = 0.33), but high and significant for the gymnasts (r = 0.72; p < 0.05) is interesting, since it indicates that the battery would be immune to the age effects when dealing with children with no experience in AG. In the talent selection this characteristic contributes to the test's universality, once the natural ability to perform the tasks would be independent from the age group within the studied range, being more closely associated with body control and physical potential. On the other hand, the fact that the correlation is significant in the gymnasts group is positive for the theoretical consistence of the battery, since the girls involved are good performers and are experienced in AG. Therefore, they have more training time as well as a greater degree of physiological maturity.

Concerning this last aspect, it is worth remembering that age influences since older girls can have more strength and muscular power, considering that the maturation effect in the physiological characteristics are associated with the development of these variables[14-15]. As well highlighted in the literature, the testosterone and tiroxine peaks can widely contribute to the increase of muscular mass and velocity of movement in older children (12 to 15 years old) compared with younger children (9 to 11 years old), which was the case of the ages considered in the present study. Filin[16] affirms that the main criteria for the prognostic of talents are related with the rhythms of development of the physical features and formation of motor habits, which enable the preview of the perspectives of sports improvement of practitioners in the future. Concerning AG, aspects such as strength and power are essential for good performance.

Besides the potential influence of the maturation state in the tests outcomes, the time of practice should be also considered as it interferes in the gymnasts' performance. Such aspect can be crucial in the difference between the obtained outcomes in the two studied groups. All exercises from the final tests battery are part of the daily training of the athletes, what does not occur to the children from the school. Although the identification of the percentage of the contribution isolated from the physiological aspects and the time of training in the result of the PPAG Battery cannot be identified, its means were increasing according to age (table 4). Actually, the systematic practice of a given training may cause morphological and functional adaptations[14,17].

Concerning the tests battery's trustworthiness for the calculation of the PPAG, the two strategies used showed satisfactory results. The strategy of combining an association test and another of discrimination in order to analyze the ratio between two consecutive measurements is not unusual and has been adopted by other studies with similar objective[18-19]. Such procedure reproduces the results obtained in an intra-class correlation, without the disadvantage of using ANOVA in a context which involves only two dependent variables and considering the pairing between individuals, an aspect neglected by the ICC or by the *kappa* index. The intra-observers trustworthiness presented correlation values which can be considered high (p < 0.05) between the two days of testing. The values ranged from 0.83 to 1.00, which let us affirm that the PPAG presents intra-observers trustworthiness. Examining the literature, concerning validation studies of motor tests, it can be observed that the values for association and agreement are not distant from the presently presented. Morrow *et al.*[5], for instance, list several motor activities (hitting in golf, throwing in basketball, abdominals and volleys in tennis, etc), mentioning correlations ranging from 0.54 to 0.96. Several other studies in different contexts have accepted as indicators of validation inter and intra-observers coefficients from the order of the presently obtained[10,13,18]. Concerning inter-observers trustworthiness, the outcomes were almost equal, according to what was expected, both for the activities and the PPAG. Therefore, one may affirm that the trustworthiness results found in the present study suggest that both the battery elements and its final product seem to have good trustworthiness.

Finally, it is worth mentioning some theoretical-practical aspects which are the grounding of the tests battery here presented. The first is concerned with the way the tests were selected. The statistical methods used during the study highlight the value of the final battery presented, especially since they scientifically base a set of evaluation criteria of abilities for AG, which was not performed before. It is worth mentioning that 68% of the Brazilian specialists who answered the questionnaires adopted many exercises for the selection of children for elite AG practice. However, there is neither a systematization, nor scientific support of these exercises in order to give a relative importance degree for each one in the talents selection context. Therefore, the tests battery here proposed represents an innovation when used in the Brazilian AG.

A second aspect to be discussed is concerned about the comparison of exercises adopted in the present tests battery with those which compose other batteries internationally acknowledged. Six out of the eight exercises of the tests battery used for the calculation of the PPAG are from other international tests batteries. As an example, we can mention the tests battery of the 'TOPs', used in the women's AG talents selection system in the USA, which are a world power in this sport. Moreover, five have been used by the coaches of the permanent Brazilian Team in the evaluation of athletes and four by the *Classic Challenge*[***].

Considering that the basic physical valences needed for AG mentioned by specialists and the literature are mainly strength, power and flexibility[2,20-21], the eight tests of the final battery have a great meaning, since they translate exactly the variations of these valences. Distance jump (first exercise of the equation) is related with power of lower extremities. Split exercises (second and fourth of the equation) and chest flexion (seventh of the equation) are related with flexibility of lower extremities and chest, respectively. Hip flexion exercises, rope climbing and 'arms flexion' (third, fifth and sixth in the equation) are related with dynamic strength. Finally, set-square exercise (eighth of the equation) refers to static strength. As can be seen, exercises strictly concerned with the physical valences more relevant to the AG practice were selected in order to compose the equation. One may conclude then, that the PPAG Battery presents good theoretical coherence and especially good relation with what is done in AG training internationally speaking.

Another practical important aspect to be highlighted is concerned with safety and easiness which surround the application of the present tests battery. It is understood that since the majority of the exercises of the battery is used in other tests, it reflects the safety that involves its application in children. One of the main aspects which surround the choice of a given procedure of measurement and evaluation is the easiness of its application[5]. The tests battery proposed does not involve sophisticated or costly apparels, or strict training of evaluators to measure the obtained scores. Still concerning the easiness of application, it is worth mentioning that during the research, from the pilot study until the validity and trustworthiness verification, a total of 121 tests were applied in children between 5 and 14 years of age. The experience was positive, since the children participated with no difficulty of understanding or tasks performance.

*** Classic Challenge is a competition held by the Gymnastics Training Center (GTC) which consists of nine exercises in which the children from five years of age are challenged to improve their own strength and flexibility. Further details are available at: <www.gtcgymnastics.com/classic%20conditioning.html>.

## CONCLUSION

Based on the outcomes obtained by the present study, we concluded that the majority of the AG coaches asked (68%) applies motor-physical tests in order to select children aiming elite training. Thirty different activities were mentioned by them, all compatible with what was found in the literature's review. Explanatory factorial analysis allowed the identification of a factor in which most part of the examined activities grouped, showing that they are representative of a single dimension of motor-physical skill, at least in the evaluated children. Considering that all activities were mentioned by the coaches as important for the sport's performance, this dimension could be interpreted as the *potential for performance in artistic gymnastics* (PPAG).

Multiple regression techniques allowed the identification of eight activities that best represented the twenty-two investigated ones in order to compose an equation which would discriminate the PPAG. They are namely: distance jump, split with antero-posterior opening of the right and left legs, hip flexion in suspension, rope climbing, 'arm flexion' on the floor, chest flexion and 'set-square' on the low step. The tests battery developed for the determination of the PPAG showed good levels of construct validity, crossed validity and inter and intra-observers trustworthiness.

Although the results obtained have been promising, the validation process of the test should be an object for future investigation. Some suggestions of complementary studies that can be developed are: a) studies with larger samples, making the multivariate statistics stronger concerning power and implementing the PPAG interpretation as motor-physical dimension; b) longitudinal studies of predictive validity, in order to verify the real power of prediction of the tests battery concerning future performance in AG and, therefore, of discrimination in the talents selection; c) application of the principles and approaching of the present dissertation in the designing of a tests battery for talent selection in men's AG and other sports.

Finally, it is important to highlight the innovative aspect which involves the tests battery developed, as well as the future perspectives for its application. As far as our review effort could state, the literature is scarce concerning specific tests for talents selection in AG; especially when tests whose application is simple and cheap are considered. Therefore, the tests battery here represented could constitute a procedure for aiding in the selection process of talents of Brazilian AG.

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