LOCOMOTOR APPARATUS IN EXERCISE AND SPORTS

ORIGINAL ARTICLE

USE OF BIOPHOTOGRAMMETRY FOR ASSESSMENT OF TRUNK FLEXIBILITY

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ABSTRACT

Introduction: Rhythmic Gymnastics (RG) is a type of gymnastics that requires a high degree of flexibility due to the complexity of the required movements. Objective: This study aimed to compare the sit and reach test (SRT) and the Biophotogrammetry technique as indicators of trunk flexibility in beginning GR practitioners. Methods: The sample included 60 girls (5-11 years old) from a universe of 110, all enrolled in a Center for Sports Initiation in Parana State. Data collection was performed in November, 2009. In order to compare the SRT and biophotogrammetry, angles of the pelvis (PW), spinal flexion (SW) and total trunk flexion (TW) were drawn. Results: The average score achieved by the participants on the SRT scale was 27.75 cm. A strong correlation was found between TW angle and the SRT values. Since it is a combination of the SW and PW, the TW provides a global view of the distance from the trunk to the legs when bending occurs during the test. Therefore, the correlations between the angles are good and meaningful. Conclusion: Since the SRT has some intervening factors that may mask the result, biophotogrammetry is discussed as a test that allows the observation of reliable data for measuring flexibility and muscle compensation which are not usually identified, through photographs and angular calculations.

Keywords: *angles, sit and reach test, biophotogrammetry*

INTRODUCTION

Flexibility has considerable participation and contribution in many sports modalities; however, its role especially intensifies in sports which involve aesthetical content of the perfect body figure, acting as morphofunctional priority of the locomotor system[1].

According to Dupont[2], rhythmic gymnastics (RG) is a sport in which the range of motion predicts the quality and the value of difficulty of its performance. Flexibility is the factor which is the most demanded at the competition level, since the punctuation code itself categorically requests this physical valence, leading to an extreme demand.

Thus, in this context, it is observed that controlling the level of flexibility is a crucial control factor, and that the sit and reach test (SRT) is among the most frequently used methods in flexibility evaluations. The SRT is an indirect method which enables intra and inter-subject comparisons, characterized as a test of easy performance and high practicality[3].

According to Baltaci *et al.*[4], the SRT is present in many batteries which evaluate physical fitness, since it is believed that keeping the low back and hamstrings flexibility level suitable may substantially avoid acute and chronic osteomuscular injuries, besides low back problems, posture swerves and gait limitations.

However, Cardoso *et al.*[5] comment that some factors may alter the test result such as disparity of proportion in the length of lower limbs compared to upper limbs, spine mobility and scapular abduction. Such components act as potential interference, since an individual may receive a high classification in the test even if he/she does not present appropriate flexibility.

Moreover, Chagas and Bhering[6] highlight that a high level of shoulder protrusion and of thoracic spine flexion may act as factors which alter the validity of the measures of the test under consideration, since under these conditions, the movement performance would be facilitated. However, it would not evaluate the real condition of the subject and would doubt the result of what really is wanted to be evaluated.

Some evaluators, especially in the physiotherapy field, use the kinemetry for evaluation of movements in physical valences such as flexibility and movement velocity. In that process, cameras, camcorders and specific calculation programs which capture the image and enable their careful observation as well as comparison with other images are used[5].

Based on this context and considering the SRT intervenient factors, one of the ways of also evaluating this physical component would be through biophotogrammetry, designated as an instrument of metric application in images which record human movements with high reliability[7].

More specifically, biophotogrammetry came about in the instrument context to be used in the biomechanical analysis as a bidimensional (2D) photogrammetry variable, which gives priority and tries to solve the difficulties of the body movement analysis in the environments where the professional practice aimed at health is typical. Such priority gave opportunity to the onset of suppositions which guided a systematized treatment in the image and its measurement[7].

Thus, the aim of this study was to compare the sit and reach test (SRT) and the biophotogrammetry technique as indicators of trunk flexibility in beginning participants of RG.

METHODOLOGY

This study was descriptive, observational and transversal for the images analysis. 60 female children (which corresponded to 54.5% of the universe), aged between five and 11 years were evaluated in the study. They were enrolled in a project of sport initiation in rhythmic gymnastics in Paraná state and presented the Free and Clarified Consent Form signed by their parents or legal tutors. Data collection occurred in November, 2009 and the sample was stratified in three groups: younger than seven years old (12 girls), from seven to nine years old (37 girls) and older than nine years old (11 girls).

The instruments for data collection were a Sony® digital camera of 10 *megapixels* of resolution, a measuring tape, adhesive tape and Pimaco® spheric and white surface adhesive markers of 13 millimeters of diameter. The evaluation method used was the biophotogrammetry, which consisted in a systematized process which analyzes in 2D, in which its steps and conduct are manually performed so that a representation of quantitative factors of a body movement is performed. Its main goal is to offer in numerical expression the meanings of movements which help in the data interpretation[7].

Concerning the initial posture for the SRT evaluation with bench, the child should sit in front of the bench so that the plantar region of her feet was completely rested on the wall, legs should be extended, trunk erect and fingertips of both hands touching the movable device on the bench next to the marking. The child should afterwards push the movable device with the fingertips the most as possible without touching twice or making a sudden move. The evaluator should rest hands on the child's knees in order to keep them extended during the entire test[6-8].

The standard bench used for the test consisted of a wooden box measuring 30.5cm x 30.5cm x 50.6cm. On the top of it there is a metric scale of 50 centimeters with a sliding movable device which let determine the reach of the child[9].

The images collected for analysis were of the initial and final positions of the SRT, in three trials (all photographed).

The delimitation of strategic anatomic points which enabled the measurement of angles was necessary so that this test could be analyzed through the image. The bilateral points determined were: last fluctuating rib (lateral view), antero-superior iliac spine, trochanter of the femur, lateral condyle of the femur and lateral malleolus.

These points were marked on the children by palpatory anatomy. The palpatory anatomy consists of an exploration and examination process through touch. It is used by many health professionals to help in the clinical diagnosis and treatment[10].

After the photos have been taken, they were imported to the *CorelDraw* computer program, version 12, which has instruments which permit the measurements of angles between markers, which resulted in a subsequent analysis, the results concerning the flexibility movements.

In the SRT there was the construction of three angles on the image, both at the initial and final positions. The first angle was named SW (low back spine flexion), which started on the last rib until the antero-superior iliac spine. The second angle was named PW (pelvis flexion), which started in the antero-superior iliac spine and ended in the trochanter. The third angle named TW (total trunk flexion), started on the last rib and followed until the trochanter (figures 1 and 2).

The evaluation process occurred at the time of the children's school and while a group of children was evaluated, the other girls continued having classes. Thus, a group of approximately five girls at a time was called, the girls wore the appropriate garment, and the evaluator placed the markers on the determined bone segments by palpatory anatomy

Figure 1. Initial position of the image acquisition protocol for biophotogrammetry.

Figure 2. Final position of the image acquisition protocol for biophotogrammetry.

and asked the child to perform the SRT and repeated it three times. A photo was taken at every movement and the initial preparation for the test performance was also photographed.

The distance between the child and the camera was measured with the measuring tape and marked on the ground with adhesive tape at a length which let that the image of the entire body of the child could be focused on the camera. Thus, this marking on the ground was used to photograph all the children so that a standard for the images could be kept.

The values of each angle and of each numerical result derived from the tests were transferred to a table of the *SPSS* 15.0 program which generated some statistical tests in order to collide results.

Among the tests, we can mention the frequency distribution of the variables which calculated means and standard deviations. Additionally, the Kolmogorov-Smirnov test was also performed to verify the normality of the sample and allow the application of the Pearson correlation, which measured the level of correlation between the two inferential variables of metric scale[11].

The present study met all the requirements of the Resolution 196/96 of the National Health Board and had its protocol approved in the Ethics in Research Committee of the UFPR under the number 1013.138.10.09 and CAAE 0082.0.091.000-10.

RESULTS

The profile of the studied children can be observed in table 1. In the sit and reach test (SRT), the sample obtained mean result of 27.75 centimeters.

The angular data presented normal distribution and according to table 2, since the SRT and stature negatively correlated (r = –0.283), it can be inferred that the shorter girls presented better results.

The strong negative between angles and SRT suggests that the higher the value reached in the SRT the lower the angular values. The angle which best related to the SRT was the TW. However, for the same TW values, different SW and PW compositions were found, which specifically evaluate low back spine flexion and pelvis flexion, respectively, as presented in table 3.

Table 1. Mean and standard deviation of age, stature, angles and sit and reach test (SRT).

Variables (n = 60)	Mean	SD±
Age	8.08	1.61
Stature (cm)	131.02	10.68
Angle PW°	74.37	15.16
Angle TW°	65.79	17.33
Angle SW°	59.86	26.35
SRT (cm)	27.75	6.40

Table 2. Correlation between the angle variables, sit and reach test (SRT) and stature.

Variables	PW	TW	SW	SRT	Stature
PW	–	0.657**	0.315*	–0.425**	–0.011
TW	0.657**	–	0.885**	–0.644**	0.252
SW	0.315*	0.885**	–	–0.536**	0.293*
SRT	–0.425**	–0.644**	–0.536**	–	–0.283*
Stature	–0.011	0.252	0.293*	–0.283*	–

* Statistical significance ($p < 0.05$).
** Statistical significance ($p < 0.01$).

Table 3. SW, PW and SRT values for values close to TW.

Child	TW(°)	SW(°)	PW (°)	SRT (cm)
19	69.4	49.3	87.1	28.0
22	69.5	65.4	72.7	28.3
35	69.7	73.4	63.0	21.0

In table 4 the correlation between the angular variables and the SRT are found for the different age groups studied (group 1: five to seven years; group 2: eight and nine years; and group 3: 10 and 11 years).

In group 1 strong correlation between TW with SW and with the SRT was observed. In group 2, it was observed that the TW and SW relation and with PW follows the same pattern from group 1; however, its relation with SRT changes to a light correlation, which related with PW and SW is not significant anymore. Group 3 presented moderate correlation of TW with SW and SRT; however, the relation with PW differently from the other groups, ends up being the highest of all.

Thus, both in the global and stratified per ages analyses the SRT bettr correlated with the SW (spine) than with the PW (pelvis).

Table 4. Correlation between the angle variables and the sit and reach test (SRT) for the different age groups (group 1: five to seven years; group 2: eight and nine years; and group 3: 10 and 11 years).

Group 1 (n = 19)	PW	TW	SW	SRT
PW	–	0.627**	0.444	–0.600**
TW	–0.627**	–	0.916**	–0.897**
SW	0.444	0.916**	–	–0.792**
SRT	0.600**	–0.897**	–0.792**	–
Group 2 (n = 30)				
PW	–	0.539**	0.133	–0.253
TW	0.539**	–	0.902**	–0.422*
SW	0.133	0.902**	–	–0.333
SRT	–0.253	–0.422*	–0.333	–
Group 3 (n = 11)				
PW	–	0.882**	0.612*	–0.587
TW	0.882**	–	0.880**	–0.706*
SW	0.612*	0.880**	–	–0.691*
SRT	–0.587	–0.706*	–0.691*	–

* Statistical significance ($p < 0.05$).
** Statistical significance ($p < 0.01$).

DISCUSSION

Concerning the anthropometric profile of the children, the study demonstrated that the mean value reached by the sample in the SRT is above the *Physical Best*[12], suggested proposal, in which it is established that the child should reach a minimum of 25 centimeters in the test.

The evaluated children are also in agreement with the standard determined by the reference tables of the *FITNESSGRAM*[13], in which, for the female sex, the values comprehended between 23 and 28 centimeters indicate a healthy zone of physical fitness (ZSApF).

In the study by Venturi *et al.*[14], the flexibility of 22 girls aged between six and 10 years and practitioners for one year of classical ballet and educational dance, was evaluated with the SRT. In the results, the girls who practiced ballet reached mean of 28.82cm, and the girls who practiced educational dance reached 21.55cm in the test.

When confronting the mentioned study with the results of the SRT of the present study (27.75cm), it can be observed that the results obtained by the girls who practiced ballet are similar. Probably, this can be explained by the vast use of flexibility from both ballet and RG[15].

On the other hand, in another study conducted with 87 students, aged between six and 17 years, divided in two groups (six to 12 years and 13 to 17 years), the mean of the SRT of the younger girls was 15.4cm and the mean of the older girls was 16.1cm, results much below than the ones found in the assessed sample[16].

Moreover, it was observed in the results of the present study that the younger girls obtained better result in the SRT. In a study carried out with 420 children and adolescents from seven to 17 years old from both genders, it was observed that flexibility points out tendency to decrease in the results with age progression and, when sexes are compared, the female sex presents better results[17].

Due to the negative correlation of the angles with the SRT, it was observed that the higher the value reached in the SRT the lower the angle values. It is believed that the correlation was not even higher due to the fact that in girls with hamstring shortening, with restriction of pelvic movement, there was a compensation with the low back spine, since when the hamstrings are shortened, the pelvis cannot perform anteroversion and consequently, the low back spine increases curvature to compensate for the performance of the required movement, causing the angles not to present a homogeneous variation among subjects with the same SRT value (table 3).

The explanation of the pelvic behavior is in agreement with Alter[18], who states that when an anterior pelvic inclination is performed, the ischial tuberosity (origin of the hamstring) is placed at a superior position and later more distant from the proximal and fibular tibial insertions of the hamstrings, causing the musculature to be more elongated. However, if the individual performs a compensation pelvic movement, it is said that this fact occurred due to the combined flexion patterns of the cervical, thoracic and lumbar spine, which follow a concept based on the "lumbar-pelvic rhythm" behavior[19]. In other words, since the pelvis posteriorly rotates to follow the dorsal curvature, the ischial tuberosity ends up anterior and lowly dislocating, placing the origin of the muscle closer to its insertion.

It is natural for the body to try to compensate for the increased tension on the hamstrings, taking a back positioning which results in less musculo-tendinous tension. Thus, it is understood that the dorsal rounding is a trial to dribble the movement and reach further with the hands, since, using such strategy, the spine will not need to perform too many linear or angular dislocations, requiring less range of motion. Besides that, the cumulative flexions which occur along all vertebrae may create an illusion of high stretching level of the hamstrings[18].

In the study by Cardoso *et al.*[5], an angle similar to the PW was used to evaluate the stretching of the hamstring muscles. According to the authors, in the sit and reach test only the reach of the fingers at the most distant point , rather than the angle made by the hip joint is considered, which may predict with more accuracy the length of the hamstrings.

Thus, to consider only the reach of the fingers in the SRT may mask some intervenient factors such as differences in proportion between lower and upper limbs, spine mobility and reach[3,20,21].

In this study strong correlation of the TW angle and the SRT was observed. This angle ends up being a composition of the SW and the PW, enabling a global visualization of the trunk distance until the lower limbs when it performs the flexion the test requires. Therefore, the correlations of the TW and SW and TW and PW are good and significant.

The research by Cardoso *et al.*[5], as well as the present study used the angular kinemetry with the SRT; for that reason, it built a reference angle of the pelvic region made of the anatomic points antero-superior iliac crest and trochanter major. In their results, high intra and inter-observer reliability was found.

In the study by Miñarro *et al.*[3], to compare the SRT validity with a modified version, the *back-saver sit-and-reach* (BS), in which one of the legs should be extended while the other is flexed during the test performance, the thoracic spine lumbar spine and pelvis angles measured by an inclinometer were used as a criterion test. The low correlation of the BS evidenced that the SRT reached better validity when correlated with the criterion test, besides being of easier application and performance.

In another study, the SRT, the BS, another modified version named *modified sit-and-reach test* (MSR), in which the reach is controlled and the *toe touch test* (TT), which is performed by the standing trunk flexion are compared. The criterion test used was the *passive straight leg raise test*, in which the leg is passively raised and the angulation formed is measured by an inclinometer. All tests had moderate validity to estimate flexibility of the hamstrings; however, the authors recommend that doctors, physiotherapists and researchers adopt an angular test for measurement of the muscular length[22].

The SW angle suffered influence of the stature, which is biomechanically explainable, since during growth the trunk increases its size longitudinally, causing the spatial disposition of the markers to be more distant in taller children, consequently leading to higher angle value.

According to Haywood and Getchell[23], in the relative growth, the legs grow faster than the trunk and the head in the first and second childhoods. Afterwards, in adolescence, there is the growth spurt, in which there is mainly increase of the trunk up to the adulthood.

Flexibility of the hip and spine joints is an important attribute for the RG practice. The current punctuation code establishes in the routine compositions, 10 movements of higher complexity, which require from the gymnast high articular amplitude and high level of flexibility[2,24].

However, since flexibility is specific in each region, it is difficult to accurately measure and evaluate flexibility in general[25]. Nevertheless, some specialists recommend that the flexibility measurement of the low region of the back, hip and of the hamstrings should be included in the evaluation protocols. When these regions present low levels of flexibility biomechanical alterations which induce to patellofemoral dysfunction, low back pain, athletic pubalgia, tendinitis and posture swerves may occur[5,22,26-28].

Liemhon[29] observed that there is low performance in this test due to the compensation between the muscular groups which generate rounding of the upper dorsal region. It was also verified that there may be compensation due to extreme flexibility of the lumbar region which reflects in a satisfactory score in the test, as found in the present study.

Thus, in this study the biophotogrammetry was able to accurately evaluate the body segments which presented movement restriction or good mobility, facilitating the identification of compensations during the SRT performance.

CONCLUSION

Although the SRT is a test widely used in evaluation batteries, it has been demonstrated that it ends up producing non-reliable data, since there are many components which corroborate to the inaccuracy of the test. Thus, the biophotogrammetry, joined with the SRT, provides reliable data for the measurement of the stretching of the hamstring and paravertebral muscles, specifically, as well as the trunk anterior flexion at a global level.

It also enables a longitudinal follow-up, since the images show with property the test performance manner, as well as the possible compensations, making it possible to visualize the athletes' evolution in continuous evaluations. Additionally, it allows suitable training prescription since those athletes who present lower flexibility perform different exercises from those who present higher flexibility, with the purpose to prevent injuries by unfavorable training loads.

All authors have declared there is not any potential conflict of interests concerning this article.

REFERENCES

1. Karloh M, Santos RP, Kraeski MH, Matias TS, Kraeski D, Menezes, FS. Alongamento estático versus conceito Mulligan: aplicações no treino de flexibilidade em ginastas. Fisioter Mov 2010;23:523-33.
2. Dupont PH. Suivi medical et souplesse lombo-pelvienne en gymnastique rythmique. J Traumatol Sport 2005;22:208-13.
3. Miñarro, PAL, Andújar, PSB, García, PLR. A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students. J sports sci med 2009;8:116-22.
4. Baltaci NU, Tunay V, Besler A, Gerçeker S. Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. Br J Sports Med 2003;37:59-61.
5. Cardoso JR, Azevedo NCT, Cassano CS, Kawano MM, Âmbar G. Confiabilidade intra e interobservador da análise cinemática angular do quadril durante o teste sentar e alcançar para mensurar o comprimento dos isquiotibiais em estudantes universitários. Rev Bras Fisioter 2007;2:133-8.
6. Chagas MH, Bhering EL. Nova proposta para avaliação da flexibilidade. Rev Bras Educ Fís 2004;3:239-48.
7. Ricieri, DV. Biofotogrametria: a ciência e seus segredos. 2ª edição. Curitiba: Editora Inspirar, 2005.
8. Wells KF, Dillon EK. The sit and reach: a test of back and leg flexibility. Res Q Exerc Sport 1952;23:115-8.
9. Paiva BTB, Pey JNA, Perius D, Carvalho LO, Almeida RM, Mello PJO, et al. Comparação da flexibilidade de tronco entre cadetes do 1º ano e do 4º ano da academia militar das Agulhas Negras. REVDEF 2005;130:15-21.
10. McGaugh JM, Brismée JM, Dedrick GS, Jones EA, Sizer, PS. Comparing the Anatomical Consistency of the Posterior Superior Iliac Spine to the Iliac Crest as Reference Landmarks for the Lumbopelvic Spine: A Retrospective Radiological Study. Clin Anat 2007;20:819-25.
11. Maucher M, Kracher B, Kühl M, Kestler HA. Inferring Boolean network structure via correlation. Bioinformatics 2011;27:1529-36.
12. AAHPERD. Physical Best. Reston, VA: American Alliance for Health, Physical Education, Recreation and Dance, 1988.
13. COOPER INSTITUTE FOR AEROBICS RESEARCH. FITNESSGRAM. Manual de Aplicação de Testes. Faculdade de Motricidade Humana, Lisboa, 2002.
14. Venturini GRO, Rodrigues BM, Aidar FJ, Pace Júnior RL, Novaes JS, Mazini Filho ML. Os efeitos do ballet clássico e da dança educativa sobre a flexibilidade de meninas com 6 a 10 anos. Braz J Biomotricity 2010;1:82-90.
15. Nilsson C, Wykman A, Leanderson J. Spinal sagittal mobility and joint laxity in young ballet dancers: A comparative study between first-year students at the Swedish Ballet School and a control group. Knee Surg Sports Traumatol Arthrosc 2005;1:206-8.
16. Piñero JC, Chillón P, Montesinos JL, Sjöström M, Ruiz JR. Criterion-Related Validity of Sit-and-Reach and Modified Sit-and-Reach Test for Estimating Hamstring Flexibility in Children and Adolescents Aged 6-17 Years. J Sports Med 2009;30:658-62.
17. David ER, Montesinos JLG, Vicente JM. Diferencias en las amplitudes articulares entre varones y mujeres en edad escolar. Apunts, Med Esport 2007;153:13-25.
18. Alter MJ. Ciência da Flexibilidade. 2. ed. Porto Alegre: Artmed, 2001.
19. Cailliet R. Lombalgias – Síndromes Dolorosas. São Paulo: Manole, 1988.
20. Piñero JC, Chillón P, Montesinos JL, Sjöström M, Ruiz JR. Criterion-Related Validity of Sit-and-Reach and Modified Sit-and-Reach Test for Estimating Hamstring Flexibility in Children and Adolescents Aged 6 – 17 Years. J Sports Med 2009;30:658-62.
21. Ayala F, Baranda PS. Fiabilidad absoluta de las pruebas sit and reach modificado y back saber sit and reach para estimar la flexibilidad isquiosural en jugadores de fútbol sala. Apunts, Med Esport 2011;46:81-8.
22. Ayala F, Baranda PS, De Ste Croix M, Santonja F. Criterion-related validity of four clinical tests used to measure hamstring flexibility in professional futsal players. Phys Ther Sport 2011;7:1-7.
23. Haywood KM, Getchell N. Desenvolvimento Motor ao Longo da Vida. Porto Alegre: Artmed Editora, 2004.
24. Volpi da Silva IR, Lopez IC, Costa CGM, Gomes ZCM, Matushigue KA. Avaliação da flexibilidade e análise postural em atletas de ginástica rítmica desportiva flexibilidade e postura na ginástica rítmica. Rev. Mackenzie Educ. Fís. Esporte 2008;7:59-68.
25. Farinatti, PTV. Flexibilidade e esporte: uma revisão da literatura. Rev Paul Educ Fís 2000;14:85-96.
26. Kawano MM, Ambar G, Oliveira BIR, Boer MC, Cardoso APRG, Cardoso JR. Influence of the gastrocnemius muscle on the sit-and-reach test assessed by angular kinematic analysis. Rev Bras Fisioter 2010;14:10-5.
27. Moreira RP, Bergmann GG, Lemos AT, Cardoso LT, Nina GLD, Machado DT, et al. Teste de sentar e alcançar sem banco como alternativa para a medida de flexibilidade de crianças e adolescentes. Rev Bras Ativ Fís Saúde 2009;14:190-6.
28. Neto AG, Manffra EF. Influência do Volume de Alongamento Estático dos Músculos Isquiotibiais nas Variavéis Isocinéticas. Rev Bras Med Esporte 2008;14:104-9.
29. Liemhon W. Flexibility and muscular strenght. JOPERD 1988;37-40.