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Photogrammetric postural analysis on healthy seven to ten-year-old children: interrater reliability

Análise postural fotogramétrica de crianças saudáveis de 7 a 10 anos: confiabilidade interexaminadores

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Abstract

Objectives: To test the interrater agreement of photogrammetry used to assess postural alignment among children. **Methods:** Thirty-three variables were measured from images of 122 healthy children aged seven to ten years, that is, 58 boys (8.39±0.97 years) and 64 girls (8.42±1.06 years). A digital camera (Sony® 6.0 MP DSC-T9) was positioned on a tripod (Vanguard VT-131) at a height of 90 cm and at a distance of 300 cm from the child. The anatomical points of interest were marked with colored adhesives (Pimaco®) on polystyrene spheres of 1 cm in diameter. The children were photographed wearing a bathing suit, in the upright position, in the anterior, posterior, lateral right and lateral left views. Each photograph was analyzed by three previously trained raters using the postural assessment software SAPo. The statistical software SASS/STAT v. 9 was used to obtain the interclass correlation coefficients (ICC). **Results:** The results showed excellent interrater agreement (ICC>0.90) for 28 variables (84.85%) and good agreement (0.80>ICC>0.89) for five variables (15.15%), even with rigorous classification. **Conclusion:** This method was shown to be viable and to have the potential to generate reference data on postural alignment among children.

Key words: posture; children; photogrammetry; reproducibility of tests.

Resumo

Objetivos: Testar a concordância interexaminadores da fotogrametria aplicada para avaliar o alinhamento postural em crianças. **Métodos:** Foram mensurados 33 variáveis obtidas de imagens de 122 crianças saudáveis, 58 meninos (8,39±0,97 anos) e 64 meninas (8,42±1,06 anos), na faixa etária de 7 a 10 anos. Foi utilizada uma máquina fotográfica digital Sony® 6.0MP DSC-T9, posicionada sobre um tripé (Vanguard VT-131) com altura de 90 cm, a uma distância de 300 cm da criança. Os pontos anatômicos de interesse foram marcados com adesivos coloridos (Pimaco®) sobre esferas de isopor de 1 cm de diâmetro. Registros fotográficos foram obtidos com a criança em trajes de banho, em posição ortostática, nas vistas frontal anterior, posterior, lateral esquerda e direita. Cada registro fotográfico foi analisado por três examinadores previamente treinados que usaram o Software de Avaliação Postural (SAPo). O programa estatístico SAS/STAT v.9 foi usado para obtenção dos coeficientes de correlação interclasse (CCI). **Resultados:** Os resultados demonstram uma excelente concordância interexaminadores (CCI>0,90) para 28 variáveis (84,85%) e boa concordância (0,80> CCI>0,89) para 5 variáveis (15,15%), mesmo na vigência de uma categorização rigorosa. **Conclusão:** O método testado demonstrou ser viável e com potencial para gerar dados de referência sobre o alinhamento postural de crianças.

Palavras-chave: postura; crianças; fotogrametria; reprodutibilidade dos testes.

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Introduction

The good postural alignment is defined as a situation in which each body segment has its center of gravity vertically oriented under the adjacent segments, so that their positions are independent[1-5]. According to Van Maanen et al.[6], a normal body posture is one that confers an esthetically acceptable appearance and can be maintained for a certain period without discomfort or difficulty. When there is adequate body alignment, the musculoskeletal structures are well-balanced, therefore less susceptible to injuries and deformities[2,7]. Optimal body alignment also facilitates the acquisition of gross and fine neurological and psychomotor skills, allowing voluntary movements to be coordinated, functional and energy efficient[8-10].

Between the ages of seven and 12, postural changes take place to achieve a new balance that is compatible with the new body dimensions[11,12]. Quantitative data on the postural alignment of growing, healthy children[13-16] are scarce, and the reference values for misalignments are based on the posture of the adult population. However, it is known that a developing musculoskeletal system[16] has particular characteristics and transitory postural alignments considered abnormal in adults[16,17].

Several methods have been used to assess the alignment of body segments, such as visual analysis, X-rays[16], video cameras[6,7,18-20] and goniometry[21-25]. The use of photography as a postural record is recommended for its simplicity and low cost and for the possibility of creating a database to follow postural development[6] and, therefore, observe subtle modifications[24,26-28]. Other favorable arguments for the use of photography were presented by Niererk et al.[29], who analyzed the seated posture of adolescents by comparing low dosage X-rays (LODOX). No statistical differences were found in the analyses, suggesting that photography can be considered the gold standard for the assessment of this kind of posture. The development of this tool resulted in the creation of photogrammetry which, according to the American Society of Photogrammetry, is "the art, science and technology of obtaining reliable information about physical objects and the environment, through the process of recording, measuring and interpreting images"[25,30,31]. Therefore, this method emerges as a form of obtaining linear and angle measures with greater objectivity and reliability[3,11,30] compared to visual analysis[6].

Some methodological precautions[3,4,6] and standards[3,12,32] can be found in the literature. Results with good reproducibility and intra- and interrater agreement have been reported for most angle measures evaluated in adults[3,6,11,28,29,33]. Studies on the use of photogrammetry in children[14,17] employ various methods of acquisition and analysis, increasing the difficulty to compare the results. Nevertheless, none of the studies analyzed the interrater reliability of this method applied to children. The most studied age group is the one between seven and ten years of age, however most reliability studies analyze 15 to 17 year-old adolescents[3,18,29] and young adults[33,34] (mean age of 24 years). There is no consensus on the majority of the measures, however, it seems well-established that photogrammetry is a reliable method for analyzing posture in adults. The interrater reliability tested in the studies of Iunes et al.[11] and Normand et al.[33] showed good or excellent agreement for most of the measures.

Given the limited number of studies on postural analysis on healthy children[1,6,17,34-38], it becomes necessary to have a recording method as quantitative as possible. Thus, to improve analysis precision, even with minimal cooperation, the objective of the present study was to test the reliability of photogrammetry in a sample of healthy children. This constitutes a starting point toward reference values for postural development.

Methods

This is a cross-sectional study involving 122 healthy children between the ages of seven and ten that were submitted to a single record of postural analysis. This research project was approved by the Research Ethics Committee of Hospital das Clínicas of the Faculdade de Medicina de Ribeirão Preto - Universidade de São Paulo, protocol number 10349/2007. An informed consent form was received and duly completed by the children's parents and/or guardian, together with a registration form containing important information for inclusion or exclusion in the study. The exclusion criteria were: previous fractures in any part of the body that could have modified postural development, genetic and/or congenital diseases involving the musculoskeletal system, degenerative, neuromuscular or musculoskeletal diseases.

To obtain the data, a digital camera (Sony 6.0MP DSC-T9) was positioned on a tripod (Vanguard VT-131) 90 cm from the ground, 300 cm from the child and 350 cm from the wall. The children were photographed in a bathing suit, in the upright position, in the anterior, posterior and lateral (right and left) views. The specific anatomical landmarks were marked with colored adhesives (Pimaco®) on polystyrene spheres of 1 cm in diameter and fixed with double-face adhesive tape. The anatomical landmarks were: glabella, tragus, acromion, C7 spinous process, inferior angle of the scapula, T3 spinous

process, anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), greater trochanter of the femur, joint line of the knee, center of the patella, tibial tuberosity, a point on the midline of the leg, lateral malleolus, medial malleolus, a point on the calcaneal tendon at the level of the malleolus, calcaneus and a point between the head of the second and third metatarsals.

After the collection of the anthropometric data, the participants were instructed to position themselves on a piece of board paper. To obtain a posture as natural as possible, participants marched in place for 10 seconds. The footprint was recorded to maintain the position and dimensions of the base in the different planes. The vertical reference was obtained using a plumb line marked at every 10 cm and fixed to the ceiling. The horizontal alignment of the floor, the tripod and the camera was checked with a wooden level.

The pictures were analyzed by three different raters, as recommended by Polly et al.[39], in a reliability analysis for X-rays and in the postural analysis software SAPo®[40]. The raters were instructed to calibrate the photograph's vertical reference in SAPo® at 100% visualization and to adopt the mark of 50 cm on the previously marked plumb line. Thus, the following variables were analyzed:

- Anterior view: horizontal head alignment, horizontal acromion alignment, horizontal alignment of the ASIS, horizontal alignment of the PSIS, anterior angle of the right lower limb (RLL), anterior angle of the left lower limb (LLL), difference in limb length, horizontal alignment of tibial tuberosity, right Q angle, left Q angle, right tibiofemoral angle, left tibiofemoral angle.
- Posterior view: asymmetry between the scapulae and T3, right leg-rearfoot angle, left leg-rearfoot angle.
- Lateral view: horizontal alignment of the head, vertical alignment of the head, vertical alignment of the trunk, hip angle, vertical body alignment, horizontal pelvis alignment, knee angle.

We also analyzed asymmetry in the frontal and sagittal planes, which correspond to the projection of the center of gravity (CG) on the support base.

Table 1. Number of children according to age, weight and height.

Age	Number of children	Average Weight (Kg) and SD	Average Height (m) and SD
7 years	25	31.24±7.46	1.35±0.06
	10 Boys	32.40±9.97	1.33±0.07
	15 Girls	29.50±5.30	1.32±0.06
8 years	45	28.65±6.25	1.34±0.06
	25 Boys	27.69±7.30	1.33±0.07
	20 Girls	28.23±4.56	1.32±0.06
9 years	29	35.16±9.29	1.39±0.07
	13 Boys	36.77±8.19	1.44±0.07
	16 Girls	33.38±10.24	1.40±0.07
10 years	23	34.33±7.74	1.43±0.06
	13 Boys	36.40±8.22	1.46±0.08
	10 Girls	39.27±7.44	1.46±0.05

SD=standard deviation.

Statistical analysis

The software SAS/STAT v9 was used to analyze the agreement between the measures of the three raters by calculating the intraclass correlation coefficient (ICC). The values were classified as excellent (ICC>0.90), good (ICC between 0.80 and 0.89), fair (ICC between 0.70 and 0.79) or poor (ICC<0.70)[11].

Results

The anthropometric characteristics of the sample composed of 122 children are described in Table 1.

The ICCs were all close to 1, i.e. there was a high level of agreement between the measures of the three raters. There were no ICC values below 0.80, as shown in Table 2.

When the ICCs were classified, an excellent agreement was found for 29 variables (87.88%) and a good agreement for four variables (12.12%). Therefore, the results presented in this study suggest that the method used is reliable for children's posture analysis.

Discussion

The method tested in children showed a good to excellent agreement in all of the measures. These results are similar to those found in studies with adults[11,25,33], despite the methodological differences. They are also similar to those of Iunes et al.[11], who assessed the reliability of 22 angles in adults (24±1.9 years old) and found a poor ICC for only four angles. The researchers studied four identical variables analyzed in the present study (ASIS asymmetry, tibial tuberosity asymmetry, vertical head alignment and knee angle), and the reliability was considered excellent in both.

Normand et al.[33] assessed posture in adults with the software Posture Print and found good to excellent intra- and interrater agreement for all variables. Of the variables studied

the only angles in common with those of the present study were the horizontal head alignment angles in lateral and frontal views and the vertical head alignment in the lateral views. These angles showed the same level of agreement already demonstrated.

The reliability of different software programs was also studied. Sacco et al.[25] analyzed four postural angle measures executed by different software programs (SAPo® and Corel Draw) and found a high correlation between the data. The results suggest there is no difference in the reliability of these postural analysis programs, except for the Q angle measurement. It is believed that low interrater agreement values are due to factors extraneous to the software and are relative to image acquisition and analysis. In the first case, differences in the marking of anatomical landmarks and in marker size may interfere in the analysis and produce high variability values. Small markers hamper the visualization of anatomical references. In contrast, large markers are more visible but increase the marked area and reduce precision. The method used in the present study, derived from the SAPo® protocol, was adapted after a preliminary analysis with 25 children[41], and its reliability was verified in 66% of the variables analyzed. It is believed that the creation of a target (Pimaco® adhesive) on the marker (polystyrene spheres) and the standardization of the software's zoom at 100% were indispensable to generating greater accuracy and reducing the variability of the measures. It is also important to consider the positive effects of rater training, which took place during the preliminary study. Thus, in the present study, the interrater reliability of the postural analysis reached an ICC>80% and included all the variables.

Table 2. Intraclass Correlation Coefficient and Confidence Interval.

Measures	ICC	CI 95%
Frontal Plane - anterior view		
Horizontal head alignment	0.86	0.82-0.90
Horizontal acromion alignment	0.90	0.87-0.93
Horizontal ASIS alignment	0.95	0.93-0.96
Angle between acromion and ASIS	0.92	0.89-0.94
Frontal angle of the lower limbs (R/L)	0.93 / 0.96	0.91-0.95 / 0.94-0.97
Length difference of the lower limbs (R/L)	0.84	0.79-0.88
Horizontal alignment of tibial tuberosity	0.91	0.88-0.93
Angle Q (R/L)	0.93 / 0.94	0.92-0.95 / 0.92-0.96
Frontal Plane - posterior view		
Scapula - T3 asymmetry	0.90	0.87-0.93
Leg-rearfoot angle (R/L)	0.89 / 0.86	0.85-0.92 / 0.82-0.90
R/L Lateral View		
Horizontal head alignment (R/L)	0.93 / 0.94	0.91-0.95 / 0.82-0.90
Vertical head alignment (R/L)	0.99 / 0.99	0.98-0.99 / 0.99-0.99
Vertical trunk alignment (R/L)	0.96 / 0.98	0.95-0.97 / 0.97-0.98
Hip angle (R/L)	0.94 / 0.94	0.92-0.96 / 0.93-0.96
Vertical body alignment (R/L)	0.96 / 0.99	0.95-0.97 / 0.98-0.99
Horizontal pelvis alignment	0.91 / 0.90	0.89-0.94 / 0.88-0.93
Knee angle (R/L)	0.95 / 0.98	0.94-0.97 / 0.97-0.99
Ankle angle (R/L)	0.90 / 0.91	0.88-0.93 / 0.88-0.93
Tibiofemoral angle (R/L)	0.91 / 0.95	0.89-0.94 / 0.93-0.96
Projection of center of gravity		
Frontal plane asymmetry	0.97	0.95-0.98
Sagittal plane asymmetry	0.95	0.93-0.96

ASIS=Anterior Superior Iliac Spine; R/L=Right/Left.

Conclusion

Similar to its use in the adult population, photogrammetric posture analysis in a sample composed of children was an adequate and reliable quantitative method. Its application can contribute to the generation of reference values for children's posture. The knowledge about posture originated from studies of this nature may substantiate the detection and intervention of impairments in the developing musculoskeletal system.

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