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Reliability of fleximetry and goniometry for assessing cervical range of motion among children

Confiabilidade da fleximetria e goniometria na avaliação da amplitude de movimento cervical em crianças

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Abstract

Objective: To determine the intra and interrater reliability of fleximetry and goniometry in children and correlate the cervical spine range of motion (ROM) values obtained from these methods. **Methods**: One hundred six children participated in this study: 49 males (8.91±2.09 years) and 57 females (9.14±1.46 years). Their ages ranged from six to 14 years and symptom-free to cervical dysfunction. Two previously trained raters and two assistants assessed neck ROM. The measurements were made using fleximetry and goniometry (interrater reliability) and repeated them one week later (intrarater reliability). All measurements were made three times by each rater and the mean value was used for statistical analysis. Intraclass correlation coefficients (ICC 2.1 and 2.2) were used to investigate reliability and Pearson's correlation coefficient ($p<0.05$) was used to investigate the correlation between measurements obtained from the two techniques. **Results**: Moderate and excellent levels for intrarater reliability were observed for fleximetry and moderate reliability for goniometry. The interrater reliability was moderate and excellent for fleximetry and poor and moderate for goniometry. Significantly poor correlation was found among all neck ROM measurements obtained using both techniques, except for rotation to the left. **Conclusions**: The poor correlation between neck ROM measurements obtained from fleximetry and goniometry demonstrated that these techniques do not present interchangeable measurements. Since fleximetry presented higher reliability levels for assessments of neck ROM among children, the use of fleximetry rather than goniometry is recommended.

Key words: range of motion; cervical spine; goniometry; fleximetry; reliability; children.

Resumo

Objetivo: Determinar a confiabilidade intra e interexaminadores e correlacionar os valores de amplitudes de movimentos (ADM) cervical obtidas por fleximetria e goniometria em crianças. **Métodos**: Participaram deste estudo 106 crianças saudáveis, 49 meninos (8,91±2,09 anos) e 57 meninas (9,14±1,46 anos), com idades entre seis e 14 anos, assintomáticas para disfunção cervical. Dois examinadores previamente treinados e dois auxiliares avaliaram a ADM cervical. Os examinadores coletaram as medidas por fleximetria e goniometria (confiabilidade interexaminadores) e repetiram as avaliações, após uma semana (confiabilidade intra-examinador). Todas as medidas foram registradas três vezes por cada examinador e o valor médio foi considerado para análise estatística. O coeficiente de correlação intraclasse (ICC 2,1 e 2,2) foi utilizado para verificação das confiabilidades e o coeficiente de correlação de Pearson ($p<0,05$) foi utilizado para verificação da correlação entre as medidas obtidas por ambas as técnicas. **Resultados**: Foram observadas confiabilidades intra-examinador moderado e excelente para a fleximetria e moderada para a goniometria. As confiabilidades interexaminadores foram moderada e excelente para a fleximetria e pobre e moderada para a goniometria. Foi verificada correlação significativa e pobre entre todas as medidas de ADM cervical obtida pelas técnicas estudadas, exceto para o movimento de rotação à esquerda. **Conclusões**: A correlação pobre entre as mensurações de ADM cervical obtidas por fleximetria e goniometria demonstram que as técnicas não apresentam medidas intercambiáveis e, como a fleximetria apresentou maiores níveis de confiabilidade para avaliação da ADM cervical em crianças, seu uso é recomendado em relação à goniometria.

Palavras-chave: amplitude de movimento; coluna cervical; goniometria; fleximetria; confiabilidade; crianças.

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Introduction

Range of motion (ROM) evaluation has been widely used to quantify musculoskeletal deficits, besides serving as a basis for evaluating the efficacy of therapeutic interventions[1].

One of the most common musculoskeletal dysfunctions in the population is dysfunction of the cervical spine[2]. The prevalence of neck pain among the adult population may vary from 6 to 50%[3-5]. Estimates have shown that 67% of individuals will suffer from neck pain at some time during their lives[6]. Among children the estimates of neck pain complaints may range from 19% to 43%[7-10].

To diagnose cervical dysfunction, clinical evaluation is commonly applied[2]. Thus, ROM verification has been used as an integral component of this procedure[1,10,11], both among individuals presenting symptoms of cervical dysfunction[2,11,12] and among individuals without such symptoms[13].

Recently, several instruments have been developed for cervical ROM evaluation, going from simple devices such as fleximeters[14] up to electromagnetic computerized kinematic analysis systems[15] or three-dimensional ultrasound equipment[1,16]. However, these equipments are generally becoming more and more complex, for use in specific segments. Their cost is high and therefore not very accessible for clinical practice. Thus, instruments like the universal goniometer and fleximeter stand out as simple alternatives for large-scale use at low cost.

The use of evaluation methods to define normal values and for diagnostic purposes, both in clinical practice and in research, depends on the verification of intra and inter-examiner reliability levels (when the procedure depends on an examiner to obtain the measurements) as well as verification of the validity, sensitivity and specificity of their measurements[1,17].

Some studies have shown acceptable intra-examiner reliability levels for cervical ROM measurements obtained by goniometry[18,19], while for fleximetry, the reliability levels have been found to be excellent for both intra and inter-examiner measurements[14,17,19] among adult populations.

However, although there are studies in the literature that compare the reliability levels of two or more cervical ROM measurement techniques among adults[1,18,20,21], no specific studies on children that investigated the reliability levels of cervical ROM evaluation techniques and made correlations between them were found in the literature consulted. For techniques such as goniometry and fleximetry, the volunteer's level of collaboration and capability to understand the procedure may influence the reliability levels obtained. Thus, it can be seen that it is important to conduct studies on reliability levels among this age group.

The objective of this study was to determine the intra and inter-examiner reliability of the mean values of cervical ROM measurements obtained by fleximetry and goniometry and to correlate the measurements obtained from these different techniques, among children. Cervical ROM values were also compared in relation to gender and to different age groups.

Materials and methods

Volunteers

One hundred and six children of both genders participated in this study. They were aged between six and 14 years and were students at a public school in Ribeirão Preto. Among these 106 children, there were 49 boys (8.91±2.09 years, 36.62±14.07kg and 1.36±0.13m) and 57 girls (9.14±1.46 years, 34.08±9.99kg, 1.37±0.10m). From the initial sample (n=106), 30 children who did not present reports of neck pain according to a screening questionnaire answered by the adult responsible for each child were randomly selected. From these 30 children, 29 participated in the fleximetry reliability stages and 20 children participated in the goniometry reliability stages. However, six children were absent from the inter-examiner fleximetry reliability stage and two children were absent from the inter-examiner goniometry reliability stage.

Children presenting systemic degenerative diseases (rheumatoid arthritis, lupus erythematosus, etc) or previously diagnosed cervical abnormalities, and who had undergone previous treatment for these conditions, were excluded. The adults responsible for the children signed an informed consent statement to authorize their children's participation in this study. This project was approved by the Ethics Committee of Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo (HC/FMRP-USP), procedural number 8562/2003.

Procedures

The flexion, extension, right and left rotation and right and left lateral flexion movements of all participating children were randomly evaluated (n=106). For all cervical movements, three consecutive values were obtained through the use of goniometry and fleximetry techniques by two previously trained examiners (examiners 1 and 2) and two assistants. The assistants recorded all the data collected, helped the examiners in measuring data and observed possible compensating patterns when cervical movements were being performed.

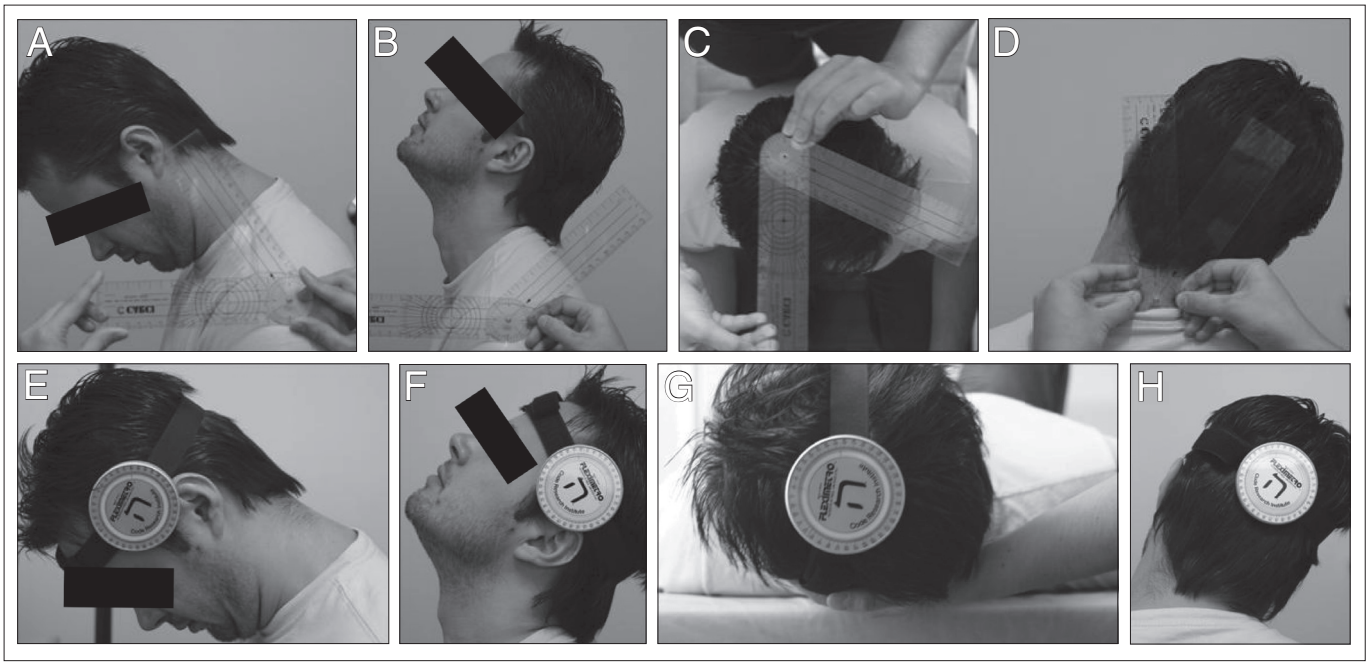

Figure 1. Description of the cervical range of motion measurements obtained by means of goniometry and fleximetry; flexion and extension (A and B): the goniometer axis was positioned at the level of the seventh cervical vertebra, the fixed arm was kept parallel to the floor and, at the end of the movement, the moving arm was aligned with the earlobe; rotation (C): the goniometer axis was positioned at the center of the head, the fixed arm was positioned at the center of the head, at the sagittal suture, and at the end of the movement, the moving arm was aligned with the nose; lateral flexion (D): the goniometer axis was placed on the spinous process of the seventh cervical vertebra, the fixed arm was placed parallel to the floor and the moving arm was aligned with the midline of the cervical spine; flexion and extension (E and F): the fleximeter was positioned at the side of the head, above the ear; rotation (G): the individual was kept lying down in dorsal decubitus, with his head above the level of the bed and shoulders touching the end of the bed. The fleximeter was positioned at the central point of the head; lateral flexion (H): the fleximeter was positioned in the region of the external occipital protuberance.

- Cervical fleximetry: fleximetry was performed using a fleximeter (Fleximeter®, Code Research Institute, Brazil)[22]. This equipment has a scale marked out in degrees (intervals of two degrees), to measure joint angles, and a tape to attach it to the mobile tracker[17].

  The measurements obtained with the fleximeter were made in accordance with the instruction manual[22]. The Figure 1 (items A, B, C and D) shows the cervical ROM evaluation procedures using fleximetry.
- Cervical goniometry: goniometry was performed using a universal goniometer (Carci® Surgical and Orthopedic, Brazil) with a measuring scale marked out at two-degree intervals.

  For cervical ROM measurements via goniometry, the measuring system developed by Kapandji[23] and Marques[24] was followed. The Figure 1 (items E, F, G and H) shows the procedures for cervical ROM evaluation using goniometry.
- Reliability of measurements obtained by fleximetry and goniometry: from the first evaluation, three consecutive measurements of each cervical movement were obtained by two previously trained examiners. Thus, examiner 1 performed the goniometry and examiner 2 obtained measurements through fleximetry. After a one-day interval, the children who chose to participate again were reevaluated by the same examiners. However, the ROM evaluation techniques were swapped between the examiners, and thus examiner 1 performed fleximetry and examiner 2 performed goniometry. After a further seven-day period, measurements were made again by each examiner (examiner 1 performed goniometry and examiner 2 obtained the measurements through fleximetry), for intra-examiner reliability verification.

Statistical analysis

The data presented normal distribution according to the Shapiro-Wilk test ($p \leq 0.05$) and therefore parametric tests were used. The interclass correlation coefficient (ICC) was used to verify the intra-examiner (ICC 2.1) and inter-examiner (ICC 2.2) reliability of the mean cervical ROM values. The ICC values were classified in the following way: <0.4 as low reliability; between 0.4 and 0.75 as moderate reliability and >0.75 as excellent reliability[25]. For correlation analysis between the values obtained by goniometry and fleximetry, Pearson's correlation coefficient was used ($p \leq 0.05$). Values of $r<0.3$ characterized poor correlation, between 0.3 and 0.5 slight correlation, between 0.6

and 0.8 moderate correlation and >0.80 excellent correlation levels[26]. The absolute and relative errors of correlated measurements were also calculated. Student's t test (p≤0.05) was used to investigate differences in mean cervical ROM values between genders, and one-way ANOVA (p≤0.05) was used to investigate differences in mean cervical ROM values between the different age groups. The homogeneity of the variances was tested using the Levene test, and the Duncan post hoc test was used to locate the differences.

Results

Intra and inter-examiner reliability

The intra-examiner reliability of the mean cervical ROM values obtained via goniometry was considered moderate for all cervical movements (Table 1). Among the fleximetry measurements, the intra-examiner reliability for the mean values of flexion, extension, right rotation and right lateral flexion was moderate and it was excellent only for the mean values of left lateral flexion (Table 1).

The ICC values for inter-examiner reliability obtained via goniometry were poor for flexion, extension and right lateral flexion movements and moderate for right and left rotation and left lateral flexion movements (Table 1). For inter-examiner reliability, the measurements obtained via fleximetry were moderate for the mean values of right rotation and left lateral flexion and excellent for the mean values of flexion, extension, left rotation and right lateral flexion (Table 1).

Table 1. Intraclass correlation coefficient (ICC) values for intra and inter-examiner reliability of the values for cervical range of motion obtained by means of fleximetry and goniometry.

Movements	Fleximetry		Goniometry	
	Intra (n=29)	Inter (n=23)	Intra (n=20)	Inter (n=18)
Flexion	0.66	0.78	0.46	0.15
Extension	0.69	0.89	0.54	0.26
Right rotation	0.75	0.46	0.43	0.49
Left rotation	0.72	0.79	0.45	0.60
Right lateral flexion	0.72	0.82	0.47	-0.07
Left lateral flexion	0.77	0.70	0.44	0.50

Correlation between the values obtained via goniometry and fleximetry

A statistically significant correlation was found between the mean values of flexion, extension, right rotation and right and left lateral flexion between the two techniques (Table 2). However, the correlation for all movements was considered to be poor (0.24<r< 0.39) (Table 2).

Differences between genders and ages

Significant differences were found between the genders for the mean values of cervical spine flexion obtained by goniometry and for the mean values of right and left rotation obtained by fleximetry (Table 2).

In groups divided according to the ages considered in this study, significant increases in the mean values of right rotation for the age groups of 9 and 10 years and left rotation only for 10 years of age were found among the measurements obtained via goniometry (Table 3). A significant decrease was found for the mean values of right lateral flexion in the age group of seven years, with a subsequent increase at 8 years and new decrease at

Table 2. Correlation between the mean values for cervical range of motion obtained by means of fleximetry and goniometry (n=106), and gender differences between the mean values for cervical range of motion obtained using both techniques.

Movement	Device	Mean value±sd (degrees)	Correlation strength	Mean absolut error (degrees)	Mean relative error (%)	Girls (n=49)	Boys (n=57)
Flexion	Fleximeter	58.96±10.29	0.26*	2.77±1.29	4.53±2.17	57.94±9.79	60.14±10.83
	Goniometer	47.03±10.16		2.04±1.22	4.35±2.80	44.88±10.31	49.53±9.48**
Extension	Fleximeter	64.93±10.08	0.24*	2.93±1.56	4.31±2.30	63.90±9.73	66.12±10.43
	Goniometer	66.93±13.74		2.02±1.38	2.94±1.97	65.40±12.75	68.70±14.75
Right rotation	Fleximeter	83.17±9.98	0.38*	3.01±1.83	3.50±2.07	85.50±8.81	80.45±10.63**
	Goniometer	60.35±10.45		1.69±0.89	2.78±1.49	61.30±10.76	59.24±10.08
Left rotation	Fleximeter	86.87±9.15	0.18	2.87±1.34	3.21±1.50	88.48±8.06	84.99±10.03**
	Goniometer	62.37±9.61		1.99±1.85	3.07±2.28	62.14±10.02	62.63±9.19
Right lateral flexion	Fleximeter	36.11±6.68	0.33*	2.84±3.52	6.93±4.68	37.12±7.04	34.94±6.08
	Goniometer	29.40±9.18		1.48±0.86	5.10±3.01	30.11±10.57	28.59±7.27
Left lateral flexion	Fleximeter	35.76±6.78	0.39*	2.43±1.29	6.51±3.53	36.25±6.84	35.20±6.73
	Goniometer	32.19±8.51		1.46±0.88	4.52±2.,81	32.95±9.74	31.32±6.81

*Pearson correlation (p≤0.05); **Student's t-test (p≤0.05); absolute error (AE): obtained value-mean sample value; relative error: AEx100/obtained value.

Table 3. Mean values and standard deviations of cervical range of motion measurements obtained by means of fleximetry and goniometry for the different age groups considered (n=106).

Movement	Device	6 years (n=8)	7 years (n=16)	8 years (n=16)	9 years (n=24)	10 years (n=18)	11-14 years (n=24)
Flexion	Fleximeter	59.29±5.27	56.96±9.37	60.38±13.30	57.18±8.89	59.98±9.38	60.24±12.18
	Goniometer	45.58±9.22	43.69±9.94	44.17±10.73	45.06±9.27	50.22±11.88	51.22±8.43
Extension	Fleximeter	63.46±6.38	64.96±11.49	62.94±14.01	69.13±9.65	65.80±8.03	61.88±7.99
	Goniometer	70.08±13.96	68.77±13.04	60.83±12.00	67.75±14.01	66.70±15.53	68.06±13.77
Right Rotation	Fleximeter	78.42±11.76	80.44±10.18	82.85±13.42	87.28±6.55	85.67±9.23	80.79±8.93
	Goniometer	56.88±12.79	55.79±8.00	57.75±13.85	63.85±11.93*	64.76±7.14*	59.46±7.08
Left Rotation	Fleximeter	80.08±8.06	86.77±8.15	89.81±12.47	89.03±7.83	89.19±8.54	83.33±7.64
	Goniometer	59.67±4.13	61.81±6.40	59.27±14.32	64.83±11.35	67.37±7.31*	59.49±6.56
Right lateral flexion	Fleximeter	38.42±5.40	36.65±7.47	35.79±5.98	36.56±7.66	35.54±5.45	35.19±7.12
	Goniometer	26.92±7.47	25.85±5.20*	36.81±14.59*	31.96±9.87*	27.22±4.84	26.74±5.45
Left lateral flexion	Fleximeter	35.96±6.13	37.04±6.39	36.29±7.69	36.25±7.89	35.17±5.69	34.46±6.58
	Goniometer	30.75±6.77	32.17±8.21	35.42±14.42	31.39±8.90	32.24±5.33	31.32±5.24

*ANOVA ($p \leq 0.05$).

9 years. No significant differences were found between the mean ROM values of any of the cervical movements measured using fleximetry, for the groups divided according to age (Table 3).

Discussion

The present study was conducted to investigate the reliability of cervical ROM measurements obtained through equipment commonly used in clinical practice, *id est*, goniometers and fleximeters, and the correlation between these measurements. In addition, differences in ROM values between genders were investigated.

According to the cervical ROM reliability measurements obtained via goniometry and fleximetry, the fleximeter presented moderate intra-examiner reliability and excellent inter-examiner reliability for most of the movements evaluated.

On the other hand, in a study by Lima et al.[17], the inter-examiner reliability levels for measurements obtained via fleximetry were excellent and moderate. However, the reliability level classification values used in the study by Lima et al.[17] were different from the ones used in the present study. Thus, using the classification method of our study, the inter-examiner reliability of the fleximeter for neck rotation movement obtained in that study would have been considered moderate, while for lateral flexion it would have been considered poor. Data from Youdas, Carey and Garrett[19], who used a type of fleximeter (CROM®), agree with the findings from our study, since excellent reliability levels were verified for cervical ROM measurements.

With regard to goniometric evaluations of cervical ROM measurements, moderate intra-examiner reliability levels were obtained for all the movements considered, and moderate and poor levels of inter-examiner reliability. Tucci et al.[18], who only studied the inter-examiner reliability, found poor reliability levels for most cervical ROM measurements considered. Agreeing with the findings from our study, Youdas, Carey and Garrett[19] reported moderate and excellent intra-examiner reliability levels and poor to moderate inter-examiner reliability levels[25].

The lower reliability values obtained via goniometry in relation to fleximetry can be attributed to differences in the handling of the different equipment. In goniometry, the difficulty in locating anatomical reference points and the depth of soft tissue along the cervical spine[27] must be taken into account when placing the axis and fixed and movable arms of the equipment. Another point relates to the possibility of fleximeter attachment, which cannot be done when using the goniometer. Therefore, small oscillations in the positioning of the goniometer can impair the levels of measurement reproducibility.

In addition to the possible errors relating to the handling of equipment, there is also the error introduced by the examiner. As observed in our study and in the study by Youdas, Carey and Garrett[19], this error is greater when goniometry is considered. To perform fleximetry, the examiner has to instruct the volunteer to perform the movements and has to read the equipment at the end of the movement. On the other hand, with goniometry the examiner has to carry out the same procedures, but also needs to visually locate the anatomical structure that will be used as the reference for determining the position of the movable arm of the equipment. Among different examiners, it is therefore necessary to consider the examiner's ability to visually follow the anatomical structures that are being used. Thus, previous training of the examiners may contribute towards raising the reliability levels of goniometry for cervical ROM evaluation and minimizing the effect of these errors when performing the procedure. For jaw ROM evaluation, higher reliability values were observed after the examiners were retrained[28].

Specifically within the age group considered in this study, it is important to point out that lower levels of collaboration and understanding of the procedures were expected. This may explain the lower reliability levels obtained for the goniometry measurements, since this is a measurement that is highly influenced by errors, which are compounded through repetition of the procedure.

The correlation between the goniometer and the fleximeter was considered poor for all of the movements analyzed, except for left rotation. These findings concur with the findings of Youdas, Carey and Garrett[19], who also found a poor correlation for the flexion and extension movements of the cervical spine when they compared the measurements they obtained through the use of CROM and the universal goniometer.

Significant differences were found between the genders, in relation to measurements obtained using both techniques among this sample of children. Through goniometry, the boys presented significantly higher values for flexion movements and the opposite was observed with fleximetry, since the girls presented higher values for some cervical movements (rotations).

The findings from the present study partially agree with those of Chen et al.[29], who conducted a review to compare studies on cervical spine ROM with different measurement equipment. They reported that, in most of the studies on adult populations, women presented higher cervical ROM values than men did, although they considered these differences to be small or have no statistical significance.

On the other hand, the findings from the present study do not agree with those of Mannion et al.[1] and Hole, Cook and Bolton[21], who did not find any significant differences between the genders when using different cervical ROM evaluation equipment on adults. The explanation for these differences in the observed values between the genders may be related to hormonal alterations and their different actions on the different genders[7]. However, since these differences disappear among adults, it is unlikely that hormonal differences are the explanation for the differences between the genders observed in our study. On the other hand, such statistical differences may have little importance in clinical terms, since the standard deviation (sd) exceeds the estimative difference. Moreover, although there are differences between the genders, the cervical ROM values obtained by both instruments are greater than the normal range described for adults[30].

In relation to age progression, in our study, significantly increased mean values of rotation and lateral flexion movements were found when the measurements were obtained through goniometry in the age group from 8 to 10 years. However, no significant differences were found between the groups divided according to age, in the measurements obtained using fleximetry. In general, increased ROM for rotations and lateral flexions was observed between the ages of 8 to 10 years, followed by a significant decrease in these values.

Differing from the findings of this study, a tendency towards decreasing cervical ROM with age progression is mentioned in the literature. This may be linked with joint alterations relating to the aging process[31]. However, our findings cannot be directly compared with the existing findings in the literature, since no studies evaluating cervical ROM among children were found.

Conclusions

The present study showed that for children in the age group from six to 14 years, no differences in the measurements via fleximetry were found. Between genders, fleximetry was capable of showing differences for a greater number of cervical movements, although these differences were statistical and not clinical. The poor correlation between the cervical ROM measurements obtained through fleximetry and goniometry showed that these techniques did not present interchangeable measurements. Since fleximetry presented higher reliability levels for the cervical ROM evaluation on children, its use is more recommended in relation to the use of goniometry.

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