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Original Article

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A Study on the Validity and Test-retest Reliability of the Measurement of the Head Tilt Angle of the Smart Phone Application 'KPIMT Torticollis Protractor'

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Purpose: The purpose of this study was to compare the concurrent validity and test-retest reliability of 'KPIMT Torticollis Protractor', a smart phone and I-pad application for convenient range of motion measurement, and 'Image J', an analysis software with high reliability and validity, according to head tilt and active cervical rotation angle. This was done to determine the clinical utility of 'KPIMT Torticollis Protractor'.

Methods: Head tilt and active cervical spine rotation angles of 40 children with congenital muscular torticollis were measured using Image J and KPIMT Torticollis Protractor, respectively. The level of concurrent validity and inter-rater and intra-rater reliability between the two measurement methods were analyzed.

Results: For forty participants, the concurrent validity between Image J and KPIMT Torticollis Protractor showed very high validity with ICC of ICC 0.977 (0.995-0.999), 0.994 (0.994-0.998), CV_{ME}% 0.71-0.72%, SEM% 0.31-0.34%, MDC% 0.86-0.94%. The test-retest intra-rater reliability showed very high reliability ICC 0.911 (0.911-0.966), CV_{ME}% 0.71%, SEM% 0.34-0.36%, MDC% 0.81-0.94%. The test-retest inter-rater showed very high reliability ICC 0.936 (0.933-0.957), CV_{ME}% 0.70%, SEM% 0.34-0.35%, MDC% 0.81-0.83%.

Conclusion: The KPIMT Torticollis Protractor, a smart phone and IPD application, is a highly reliable and valid device for angle measurement in children with congenital myotonia and can be easily used in clinical practice.

Keywords: Congenital muscular torticollis, Cervical vertebrae, Head tilt, Mobile application, Reliability and validity, Software

INTRODUCTION

In congenital muscular torticollis, the thickness of the sternocleidomastoid (SCM) muscle on the side of the lesion is wrinkled and shortened, resulting in head flexion in the same direction and rotation to the opposite side.[1] Infants with congenital muscular torticollis (CMT) will have a preference for unilateral use due to the imbalance of muscles around the neck cervical vertebrae range of motion (ROM) and strength on the unaffected SCM muscle side are assessed continuously throughout treatment. If the contracture persists, the infant will undergo surgical lengthening of the SCM muscle.[2] It is important to track changes in ROM to evaluation the effectiveness of treatment and to know when to refer for surgery.[3-6] It has been reported that 90% of patients with congenital torticollis were able to recover with stretching exercises and only 10% required surgical treatment.[7] It is also important to evaluation the recovery of range of motion in order to prevent recurrence during the postoperative and subsequent treatment period. Therefore, the reliability of the measurement is important. In infant with CMT patients, ROM is an important marker in the diagnosis and evaluation of musculoskeletal disorders of the cervical spine.[8] Measurement of head and neck position in relation to range of motion is crucial in the diagnosis and assessment of patients with pain, and it has also been shown that pain due to trauma and personal illness limits cervical range of motion (CROM).[9]

In adults, passive range of motion of the neck is typically measured in a

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sitting position.[10] The reliability of measurements performed in the sitting position is affected by the type of instrument used for measurement. When passive rotation and lateral flexion are assessed using a strap goniometer, reliability is low to moderate intraclass correlation coefficient (ICC) values ranging from 0.38 to 0.64,[11] whereas when measured with an electro goniometer (ICC values ranging from 0.90 to 0.98), inter-program and intra-rater reliability is good.[12]

While there are many tools to measure head deviation in adults and infant,[13,14] there are limitations to using these methods in infant. Some studies have compared passive measures of neck ROM in infant.[3] A few studies have assessed active ROM and passive lateral flexion in combination.[15,16] Some methods also use radiographs of head tilt,[17] an objective symptom of CMT. These have the disadvantage of being uncooperative and time-consuming during examinations in infant or young children.[18,19] However, there is a lack of fundamental methods to assess the head. In addition, the use of three-dimensional (3D) scanning equipment is limited by the fact that CMT assessment is generally subjective in clinical practice and infant are often uncooperative. Furthermore, the size and weight of the equipment is prohibitive for clinical use. Classic mechanical devices include goniometry, inclinometry, and the CROM device. These devices have been the mainstay of ROM measurement in clinical practice,[20] but they have the limitation of not being able to record measurements in real time and are time consuming.[21] On the other hand, protractor applications on IT devices have the advantage of being easy to handle, relatively inexpensive compared to other diagnostic devices, and capable of recording and capturing continuous motion in real time to scan and measure the entire process of motion.[22]

Currently, various anthropometric applications using smart phone applications are being used as clinical assessment tools. Validity and reliability studies have been conducted on smart phone applications to measure the angle of the spine and the ROM of the shoulder, ankle, and neck using arthrogoniometers and compared to conventional measurement devices.[23]

Image J is an image processing and analysis program that can read both image file formats and raw formats. It can display, edit, analyze, process, save, and print images, as well as measure distances and angles. It has been shown to be a highly reliable assessment tool in many studies and a number of papers measuring forward head posture. This program has also been used to measure head and cervical spine angle using this program.

The Korea pediatric integrative manual therapy (KPIMT) Torticollis Protractor (KTP) application used in this study is a typical smart phone application that utilizes the smart phone's camera to measure angles. To overcome the limitations of manual assessment tools, immediate assessment results and feedback using smart phone applications have been widely used clinically,[24] in addition, unlike J image, it is an application that allows you to check the angle immediately by simultaneously recording video and measuring the angle in real time using a smart phone or iPad within the treatment time. But there is a lack of research on the validity and reliability of small inter-joint angle measurements, such as head tilt and spine angle, although studies have focused on large inter-joint measurements such as knee and shoulder joints.

Therefore, this study aimed to determine whether an IT device application can be used to measure the head tilt angle and active cervical rotation angle of CMT patients in the supine position in infant with CMT before the age of 6 months, and to suggest that it is a suitable device that can be used for joint range of motion measurement in research and clinical practice, and has the potential to perform diagnosis and evaluation in the treatment of musculoskeletal diseases. In addition, we wanted to secure reliability through inter-program and intra-rater reliability assessments to determine the level of agreement of the application's measurement results in relation to the protractor.

METHODS

1. Subjects

Forty-six children (29 males and 17 females, actual age 4.5-6 months) were recruited through outpatient visits to a pediatric torticollis rehabilitation center in Yongin City, Gyeonggi-do. The children were referred for treatment of plagiocephaly and CMT. Assessments were performed by pediatric physiotherapists, each with more than 10 years of clinical experience.

Participants were included in the study if they had a diagnosis of plagiocephaly as documented in their medical records and reported by a pediatric physiotherapist. To ensure the validity of the measures, infants diagnosed with other types of neurological pre-existing injuries such as neurological torticollis, Sandifer syndrome, benign paroxysmal torticollis, and other non-muscular types of torticollis were excluded from the study, as were patients whose parents refused to give informed parental consent. Forty-six participants (29 males and 17 females) were recruited. In the end, 6 out of 46 patients were dropped due to surgical progression of fibroids, leaving a final 40 patients. Seventeen infants (10 males and 7 females) were diagnosed with left-sided CMT, and twenty three infants (16 males and 7 females) were diagnosed with right-sided CMT. All participants have a diagnosis of plagiocephaly; 7 of them have a medical diagnosis of bilateral

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hip dysplasia; and 4 of them have a diagnosis of brachycephalic and 2 of them have a diagnosis of dolichocephalic.

This case study was conducted after obtaining informed consent in accordance with the Declaration of Helsinki.

2. Measurements

1) Image J

Image J (Version 1.46, National Institutes of Health, USA) was selected as the gold standard software to compare the KPIMT torticollis protractor in this study. Image J is a highly reliable software that measures body angles, body part widths, and lesion size based on photographic images and is widely used in orthopedic and neurological research.[26]

2) KPIMT Torticollis Protractor

In this study, Image J was selected to compare the KPIMT Torticollis Protractor application. KPIMT Torticollis Protractor is a software that measures head flexion angle and cervical spine rotation based on still photographs after checking the correct posture based on the images taken.

'KPIMT Torticollis Protractor' is an IOS-based application that can measure the angle of various points in a video. 'KPIMT Torticollis Protractor' allows you to take new videos and import existing videos from your photo album and measure the angle by dragging the slider frame by frame and searching for a specific time. This software has the advantage of being able to measure easily with mobile phones and iPads, and it is easy to analyze the results because the results can be derived immediately after recording.

3. Procedures

A designated clinic room was used to collect data for the study. The data collection procedure was 5-10 minutes per child. One of the pediatric physiotherapists placed the child in the supine position and immobilized both shoulders according to the assessment method of Cheng et al.,[3] and a colleague pediatric physiotherapist directly launched the tablet application and proceeded with the filming.

The measuring therapist ensured that the tablet was set to display the current date and then used the KPIMT Torticollis Protractor application on the tablet to image the child in the supine position to measure the lateral tilt of the head and active cervical rotation angle.

The evaluator, a pediatric physiotherapist, first filmed each head tilt and active cervical rotation angle and then captured the video with a video recorder, repeating the procedure five times for optimal results. If the child was uncooperative, CMT with patient was sedated and filmed again. The order of the angles was alternated during the filming.

At the end of each data collection day, the principal investigator's video and two of the five captured stills were downloaded and printed out to control for the evaluator's bias in the processing of the stills. After that, folders were created in a designated folder using the initials of each photographer's name and numbered 1 to 5, respectively, and the other photographers saved the stills in the order of the folders.

After data collection for the entire study was complete, the folder was unlocked and all measurement data was collected for analysis. We maintained a weekly interval between measurements, alternated measurements with photos taken by different investigators, and ensured that investigators could not recall previous measurements and could not access previously collected data for the same participant. This ensured control for rater bias.

The measurement procedure was performed using the KPIMT Torticollis Protractor application, with one line drawn through the participant's eye and the other through the upper aspect of the acromion (top of the lateral third). Measurements were recorded on paper with captured photographs and signed by the investigator.

4. Statistical analysis

To compare with Image J, the final measurements taken with the KPIMT Torticollis Protractor were presented as the mean and standard deviation (SD), and the intra-rater and inter-rater differences were analyzed with paired samples t-tests to determine statistical significance. The general characteristics of the participants were analyzed with descriptive statistics. The validity of KTP as an angle measurement for postural analysis was tested using intra-class correlation coefficients (ICC).[26,27]

According to Portney,[24] an ICC < 0.750 indicates moderate reliability, 0.750-0.900 indicates good reliability, and ≥ 0.900 indicates excellent reliability. The statistical significance of the measurements was calculated to evaluate intra-rater reliability for the KPIMT torticollis protractor measurements using paired t-tests. Additionally, the inter-rater reliability and validity of Image J and KTP were tested using ICC.[28]

Measurement errors were analyzed with the standard error of measurement (SEM). SEM was calculated using the larger of the two SD values as $SD \times \sqrt{(1-ICC)}$. Additionally, to verify if the participant measurement data had a 95% confidence level (CI), the minimal detectable change (MDC) was calculated as $1.96 \times SEM \times \sqrt{2}$, and the MDC was converted to MDC 95% as a percentage of the mean.[29]

For the analysis of measurement error, the (SEM) was used, and the

SEM was calculated as SD × √(1-ICC) using the larger of the two (SD) values. In addition, the minimum detectable change (MDC) value was used to determine whether the subject's measurement data was represented at the 95% confidence level. Detectable change (MDC) was calculated as 1.96 × SEM × √2, and the calculated MDC was converted to a percentage of the mean to calculate a 95% MDC.[29]

To compare the data on the angles of Image J and KPIMT torticollis protractor in absolute terms, coefficients of variation of method errors (CVME) and 95% limits of agreements (95% LOA) were calculated.[30]

Lower limit = Mean of difference - (1.96 TIMES standard deviation of difference)

Upper Limit = Mean of difference + (1.96 TIMES standard deviation of difference)

CV_{ME} data were calculated using the standard deviation calculated from the data of each measurement tool to calculate the coefficient of variation and converted to a percentage ($ME = Sd/\sqrt{2}$, $CV_{ME} = 2_{ME}/(X1+X2) \times 100\%$).[31] Data were calculated using Microsoft Excel (Version 2022, Microsoft, USA). Statistical analysis of statistical significance of the measurements and intra-rater reliability of inter-rater agreement were analyzed using the Window SPSS (Version 24.0, IBM Co., USA) program. All statistical significance levels were set at 0.05.

Table 1. General patient characteristics

Variables	Mean±SD		$\chi^{2/F}$
Sex (n)	Male (26)	Female (14)	0.563
Age (days)	109.2±18.2	114.4±18.7	4.134
A-SCM (mm)	1.67±0.18	1.66±0.14	0.149
Head lateral flexion (°)	18.90±0.87	18.69±0.47	1.388
Cervical rotation (°)	34.47±5.24	33.18±2.53	1.541

Values are presented as mean±standard deviation. A-SCM: sternocleidomastoid muscle thickness on the affected side, Rotation: degree of head rotation on the affected side.

RESULTS

This study was conducted on 40 subjects, excluding 6 dropouts, whose general characteristics are shown in Table 1. The results of the head and

Table 2. Comparison of Image J and Torticollis Protractor head tilt and cervical rotation angle concurrent validity

	Protractor	Image J	ICC (95% CI)	CV_{ME}%	SEM%	MDC%	95% LOA
Head tilt angle	18.14±0.74	18.25±0.81	0.977 (0.995-0.999)	0.72	0.31	0.86	-0.64-0.73
Cervical rotation angle	34.14±0.34	34.27±0.71	0.994 (0.994-0998)	0.71	0.34	0.94	-1.13-1.14

Values are presented as mean±standard deviation. ICC: intra correlation coefficient, 95%LOA: limits of agreements, CVME%: coefficients of variation of method error %, SEM%: standard error of measurement %, MDC%: minimum detectable change %.

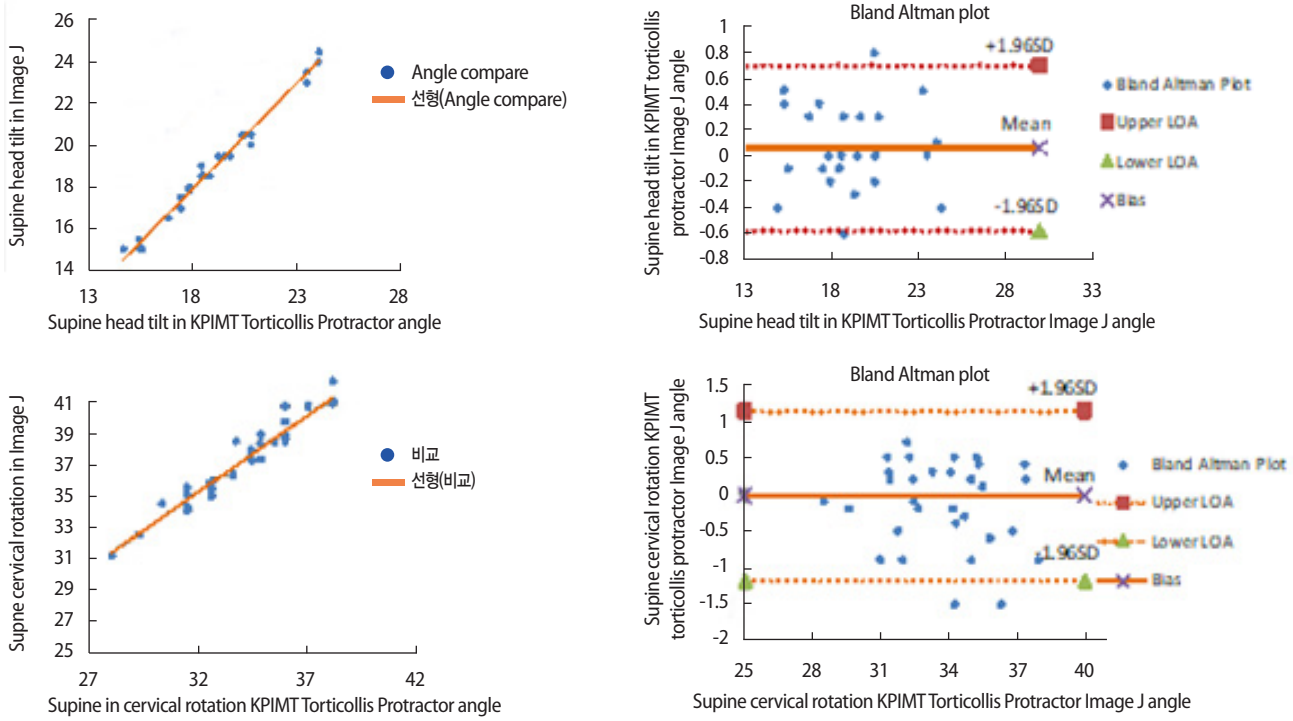

Figure 1. Bland and Altman graph for the relationship between Image J and KPIMT Torticollis Protractor

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spine angles measured with the KPIMT Torticollis Protractor by Measurer A and Measurer B were analyzed for inter-test, intra-rater and inter-rater reliability significance using paired t-tests. The results showed that the significance level was 0.554 within the measurer, 0.719 between the measurers, and 0.563 between the devices, and all variables were not significantly different at 0.05 or higher.

As shown in Table 2, the ICC (2, 1) for the consistency in measurements of the head tilt angle and cervical rotation angle between Image J and KTP was high at 0.977 (0.995-0.999) and 0.994 (0.994-0.998), respectively, and the CV_{ME}% was low at 0.71% and 0.72%, respectively, and 95% LOA indicated an even distribution at -0.64 to 0.73 and 1.13-1.14, respectively (Table 2, Figure 1).

The ICC (2, 1) for intra-rater reliability in the head tilt angle and cervical rotation angle measured with KTP indicated high reliability at 0.911 (0.911-0.966) and 0.924 (0.922-0.971), respectively (Table 3, Figure 2). The CV_{ME}% was low at 0.71%, and the SEM was 0.34 for head tilt angle and 0.36 for cervical rotation angle. The MDC indicated high intra-rater reliability at 0.81 and 0.94, respectively (Table 3, Figure 2). The ICC (2, 1) for inter-rater reliability in the head tilt angle and cervical rotation angle measured with KTP indicated high reliability at 0.936 (0.933-0.957) and 0.913 (0.911-0.957), respectively (Table 4, Figure 3). The CV_{ME}% was low at 0.70% and 0.71%, respectively, and the SEM was 0.35 for head tilt angle and 0.34 for cervical rotation angle. The MDC indicated high inter-rater reliability at 0.83 and 0.81, respectively (Table 4, Figure 3).

DISCUSSION

This study aimed to examine the validity of the KTP, a smart phone app-based protractor, and to measure the inter-rater and intra-rater reliability of the measurements. To this end, we compared the craniovertebral angles measured with KTP with those measured with Image J. The ICC for reliability was high (> 0.900) for all measurements.

Table 3. Intra-rater reliability in Torticollis Protractor head tilt and cervical rotation angle

	Protractor	Image J	ICC (95% CI)	CV_{ME}%	SEM%	MDC%	95% LOA
Head tilt angle	18.88±0.83	18.69±0.79	0.911 (0.911-0.966)	0.71	0.34	0.81	-0.84-0.08
Cervical rotation angle	34.57±0.71	34.11±0.64	0.924 (0.922-0971)	0.70	0.36	0.94	-1.16-1.12

Values are presented as mean±standard deviation. ICC: intra correlation coefficient, 95%LOA: limits of agreements, CVME%: coefficients of variation of method error %, SEM%: standard error of measurement %, MDC%: minimum detectable change.

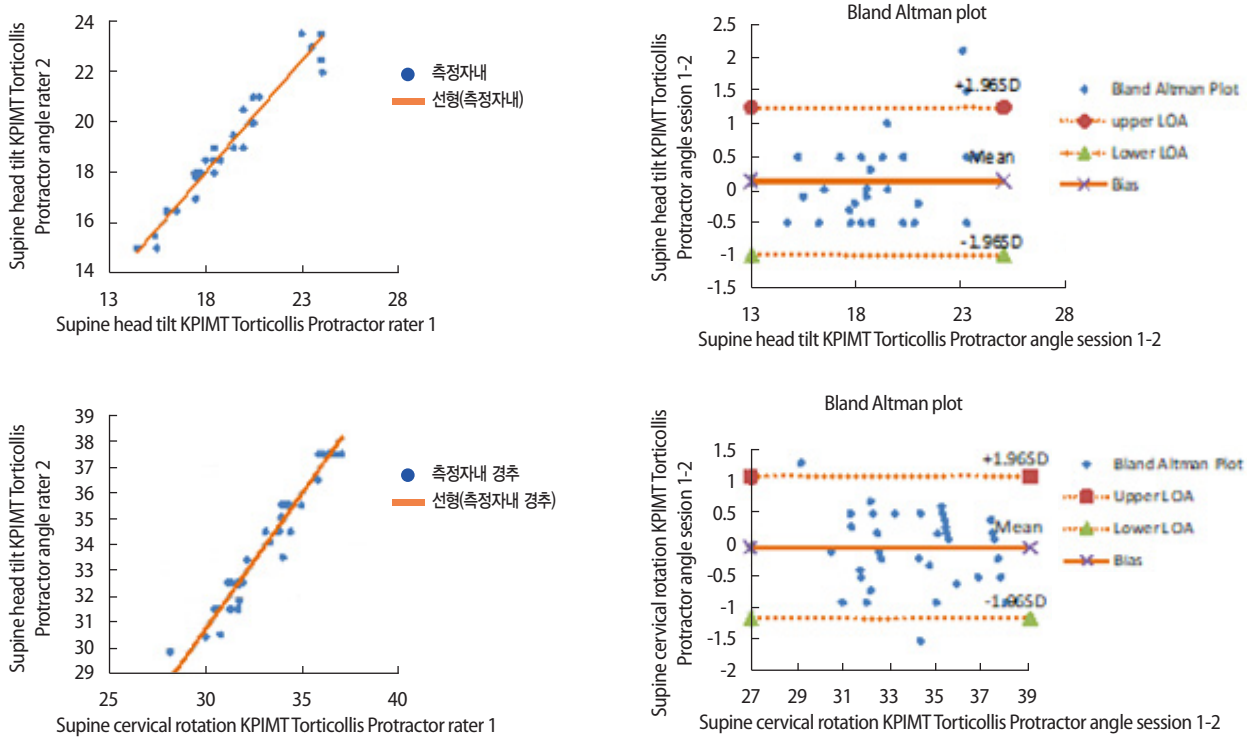

Figure 2. Bland and Altman graph for intra-rater reliability of head tilt and cervical rotation using the KPIMT Torticollis Protractor

Table 4. Inter-rater reliability in Torticollis Protractor head tilt and cervical rotation angle

	Protractor	Image J	ICC (95% CI)	CV_{ME}%	SEM%	MDC%	95% LOA
Head tilt angle	18.11±0.76	18.87±0.71	0.936 (0.933-0.957)	0.70	0.35	0.83	-1.02-1.31
Cervical rotation angle	36.01±0.83	35.87±0.44	0.913 (0.911-0.957)	0.71	0.34	0.81	-1.16-1.12

Values are presented as mean±standard deviation. ICC: intra correlation coefficient, 95%LOA: limits of agreements, CVME%: coefficients of variation of method error %, SEM%: standard error of measurement %, MDC%: minimum detectable change %.

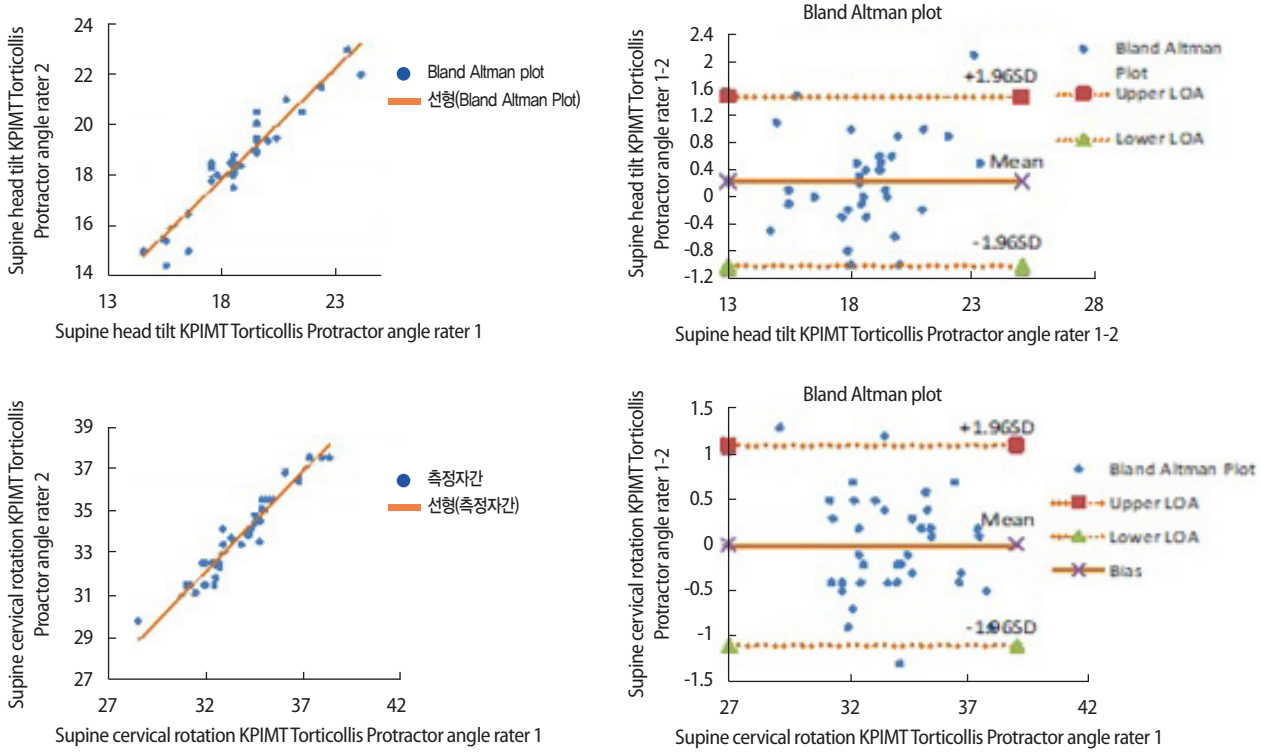

Figure 3. Bland and Altman graph for intra-rater reliability of head tilt and cervical rotation measurements using the KPIMT Torticollis Protractor

ROM is an important index in the diagnosis and evaluation of cervical musculoskeletal disorders. Measurements of head and neck positions in relation to ROM are crucial for the diagnosis and evaluation of patients with neck pain, and studies have shown that neck pain from trauma and disease limits cervical ROM (CROM). Furthermore, CROM has been found to be closely linked to whiplash injuries, and reduced CROM is a useful index for neck pain.

Pryce & McDonald[32] measured CROM in three different states: no ROM-limiting devices, use of the cervical collar, and full immobilization using a Pro-Lite spine board. The Pearson r coefficient for all measurements was high (>0.78), indicating high reliability. Our results suggest that measuring CROM is a meaningful process for examination. The existing gold standard is dynamic information capture, and the motion capture system is a prime example. However, these systems are generally used for research purposes and are costly and bulky, limiting their use in clinical settings.[33]

A joint protractor is the most commonly used clinical instrument to measure joint ROM, and with advances in smart phone technology and increased penetration, protractors using smart device sensors are currently used in clinical settings. Representatively, to confirm the effectiveness of pediatric integrative manual therapy for children with CMT, data were calculated by measuring joint angles through images before and after intervention.[34]

Image J is an image processing program that allows various measurements, including joint angles, volumes, and the surface area of diabetic foot ulcers, but the program needs to be downloaded and installed for analysis.[35-37] KTP is a smart phone application that offers high versatility and convenience for clinical use. Therefore, we analyzed the reliability and validity of KTP. Our results indicated that the head tilt angle and cervical rotation angle measurements taken with Image J and KTP were strongly

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correlated, with values of 0.997 (0.995-0.999) and 0.994 (0.994-0.998), respectively. The CV_{ME}% is used to compare the variation of measurement data between two instruments and can complement the ICC data by showing variability. The 95% LOA is used to display the symmetry of the result data, which allows for the determination of whether the level or error is within a reliable range. The CV_{ME}% was low for both the head tilt angle (0.72%) and cervical rotation angle (0.71%), measured with both instruments. The 95% LOA indicated symmetry overall, with -0.64 to 0.73 for the head tilt angle and -1.13 to 1.14 for the cervical rotation angle.[38]

In this study, we presented inter-rater MDC values in percentages, and the low range of values (0.83-1.51%) indicated that the instrument has a high sensitivity for detecting changes. Our findings confirm that KTP is a useful tool for measuring head tilt and cervical rotation angles. The key advantages of KTP are its quick feedback, convenience, and accessibility, as images are obtained using a smart device application. However, because it involves connecting lines using still frames after capturing the entire video for evaluation, it requires an accurate selection of still frames and averaging at least five frames. One limitation of this study is that the study population only consisted of pediatric patients with congenital muscular torticollis, so the outcome data cannot be generalized to all age groups and diseases. Additionally, the study measured head tilt and cervical rotation angles in a supine position, so the angles in sitting or standing positions could not be predicted. Further research should address these limitations and conduct follow-up studies to establish the validity and reliability of KTP in a broader population.

In the study variables were limited to head tilt and cervical spine rotation, changes in other functions were not studied. Furthermore, studies of the instrument need to include larger samples, and further research is needed to determine if treatment effects persist over time.

This study was conducted to demonstrate the validity and reliability of a smart phone application, KPIMT Torticollis Protractor, for measuring head tilt angle and cervical spine rotation angle, and the interrater reliability of the measurement device with Image J, which is widely used clinically. As a result of this study, the head tilt angle and cervical spine rotation angle of boys and girls with congenital myotonic torticollis using KPIMT Torticollis Protractor can be considered as a measurement program with high validity and reliability compared to existing measurement programs. If further studies are conducted to address the limitations of the study, or if further studies are conducted to measure not only head tilt and cervical spine angles but also various body angles, the KPIMT Torticollis Protractor may have high clinical utility in measuring body angles.

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