Reliability of the Universal and Invented Gravity Goniometers in Measuring Active Cervical Range of Motion in Normal Healthy Subjects

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ABSTRACT

This study examined the intra- and inter-rater reliability of the universal goniometer (UG) and invented gravity goniometer (GG) in measuring active cervical range of motion (ACROM) in 20 asymptomatic healthy subjects. Two raters randomly used both devices to measure active cervical flexion (F), extension (E), right lateral flexion (RLF) and left lateral flexion (LLF)). Each motion was measured twice by each device and was re-measured all over again within 2 weeks. The intraclass correlation coefficients (ICCs) for intra-rater reliability of measurement obtained with both devices were high to very high (ICC = 0.80 to 0.99 for UG and 0.90 to 0.99 for GG). The inter-rater reliability of measurement obtained with the GG (ICC = 0.85 to 0.96) were higher than those obtained with UG (ICC = 0.71 to 0.94). In conclusion, this study suggests that the GG measurement may be more advantage to UG measurement for assessing four ACROM in clinic setting. This is due to the high reliability and easier measurement procedures.

1. INTRODUCTION

Normal range of motion (ROM) of the active cervical spines has been often altered by disorders or pathology of the cervical spines. Neck pain and limitation of the active cervical range of motion (ACROM) are often documented when a patient visits the physiotherapy setting. Although the patient's available ACROM is frequently measured, the accuracy, quality of the technique and consistency of the measurement must be taken into account. Various commercial measurement devices have been used to measure cervical ROM in the clinical setting. In choosing the most suitable measurement device, it is important to consider whether that device is accurate, reliable, easy to use, and less expensive.

The universal goniometer (UG) is commonly used as measurement device for measuring body's joint ROM in clinics. However, the UG measurements of cervical ROM are claimed to be the least accurate, whereas its measurements of peripheral joint ROM provides less errors [1][2]. The intraclass correlation coefficients (ICCs) for rater reliability of ACROM measurements obtained with the UG have been reported as were between moderate and high reliability. Youdas et al reported a moderate to high intra-rater reliability of UG measurements of ACROM (ICC = 0.57 for flexion, 0.79 for extension, 0.72 for right lateral flexion, 0.79 for left lateral flexion, 0.62 for right rotation and 0.54 for left rotation) [2].

The gravity goniometer (GG) e.g. inclinometer, bubble goniometer or commercial cervical range of motion instrument (CROM) have also shown to be reliable in the studies of intra- and inter-rater reliability in measurements of cervical ROM. The standard inclinometer has shown a high to very high inter-rater (ICC = 0.78 - 0.91) reliability for measures of ACROM [3]. The CROM instrument has also shown a high to very high intra-rater (ICC = 0.84 - 0.95) and inter-rater (ICC = 0.73 - 0.92) reliability for all ACROM [2]

In addition to measurements of ACROM with UG or GG, the spin-T goniometer has shown a high to very high intra-rater (ICC = 0.87 - 0.98) and inter-rater (ICC = 0.75 - 0.96) reliability [4] [5]. However, the spin-T goniometer seems to be used in the laboratory setting but not the clinical setting. However, the spin-T goniometer seems to be used in the laboratory setting but not the clinical setting. Moreover, the prize of the standard inclinometer is quite high when considered to be used in normal clinical setting, comparing to the commonly use of the UG. Therefore, this study was aimed to invent the easy-inexpensive-gravity-based goniometer, in which its reliability is high enough to be used in the clinical setting.

2. METHODOLOGY

2.1 Subjects

Twenty healthy subjects, 16 females and four males aged between 20 and 32 years (mean 22.90 $\pm$ 3.19 years) volunteered to participate in the study. All subjects were free of neck pain at the time of test-

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ing and were excluded if they had sustained a cervical injury within six months prior to testing.

2.2 Reliability of ACROM measurements

2.2.1 Raters

Two raters measured of ACROM with both UG and GG in all subjects. Both raters were forth year physiotherapy students and were set as T1 for rater 1 and T2 for rater 2. To minimize bias, an additional forth year physiotherapy student read and recorded all measurements values.

2.2.2 Instrumentation

A 12-inch arms and large, plastic full-circle with 1-degree scale UG was used to measure ACROM (figure 1). The GG device (figure 1 and 2) consists of a 7-cm white-glossy 360-degree-frame that is glued on a same size aluminum plate, and 2-sided straps on each side of the plate. The GG measuring scale is 2-degree-interval. The measuring system comprises two needles; the inner most is a stable needle, which is set to the starting degrees of ROM, the outer most is the movable needle, which is moved according to the gravity. The strap is tightening around the subject's head; the measuring frame is above the ear in measures cervical flexion and extension, and on the forehead in measure the cervical lateral flexion to the right and left sides (figure 2).

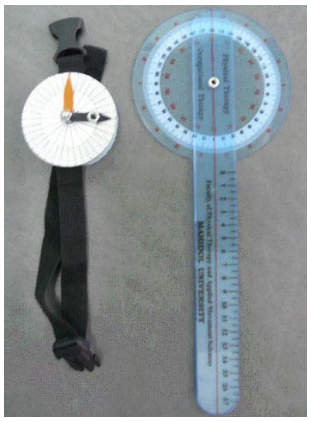


Fig.1: *The universal goniometer (right) and the gravity goniometer (left).*

2.2.3 Measurement procedure

To eliminate the errors and compensation of movement, the subjects were requested to sit upright on a straight back wooden chair with their mid thoracic contact and strapped to the back of the chair (prevent trunk extension while performing cervical extension and prevent trunk flexion while performing cervical flexion) and their arms were on the armrests (prevent lateral trunk bending while performing lateral

Fig.2: *The invented gravitation goniometer with 2-degree scale and 2 sided strap, the figures shows set up of measurement active cervical flexion.)*

cervical flexion). Subject's feet were flat on the floor and their hip and knee angles were in 90°.

Measurements were made on two sessions between two weeks apart. On each test session, each subject was measured twice in a set sequence of four ACROM by each of two raters (T1 or T2) and by each of two devices (UG or GG). Hence, each subject was measured for a total of 32 measurements in each test session. The set sequence of four ACROM was made in the same order across both test sessions. The first motion was cervical flexion, then extension, followed by right lateral flexion and left lateral flexion. Prior to the test, the subjects were asked to move their heads actively once to the end ranges of four motions by the sequence of the set. This was done to allow subjects to familiar with the test procedure and to minimize the effect of creep. Verbal instructions were the same and uniform for all measurements.

Examiner was random assigned for the measurement order and then was random assigned for usage of device. For the first rater, the first trial of the measurements obtained with either UG or GG was done in a set sequence of four ACROM, and then the sequence were repeated and recorded again. Then measurements obtained by another device were performed by the same rater. When all 16 measurements were done by the first rater, the second rater performed the measurement with the same protocol. The subjects had five-minute rest between the sequences of measurements. To minimize bias, the rater did not observe the other taking the measurements.

2.3 Data analysis

Descriptive statistics (mean ± SD) were calculated for both goniometric measurements of ACROM. Paired t-test was calculated for significance differences in degrees of AROM between raters using same device. Intraclass correlation coefficients ($ICC_{(2,2)}$) were calculated to determine the rater reliability of the UG and GG measurements. To determine within-session intra-rater reliability, ICC was calculated by

comparing the two trials of each motion taken by each rater with the same device on each test session. Each rater obtained 8 paired measurements for each session; therefore, a total of 32 paired measurements were obtained for both raters and for both sessions. To determine between-session intra-rater reliability, the averages of two trials of each motion taken by each rater on each session were calculated for ICC. Within-session inter-rater reliability was determined by comparing the averages of two trials of each motion taken by each rater with the same device on each test session. Coefficients of variation (CV) were also calculated to determine variability of the measurements of ACROM.

3. RESULTS

For each device measurements, the average of each ACROM measured on session 1 was similar to average of those measured on session 2 by each rater, and among raters (Table 1). A significance rater differences were only found for the UG measurements for RLF on both test sessions and for LLF on test session 2 ($p < 0.05$). For UG measurement, total ACROM were 52.62 ± 8.65° for F, 55.72 ± 13.14° for E, 33.56 ± 8.68° for RLF and 34.53 ± 8.47° for LLF. For GG measurement, total ACROM were 55.93 ± 10.12° for F, 64.04 ± 13.33° for E, 42.45 ± 8.35° for RLF and 41.20 ± 9.75° for LLF.

Intra-rater reliability results are shown in Table 2. Within-session intra-rater reliability was high to very high for UG measurements, ranging from $ICC_{(2,2)}$ = 0.80 to 0.99 and was very high for GG measurements, ranging from $ICC_{(2,2)}$ = 0.90 to 0.99. Between-session intra-rater reliability was high to very high for both goniometric devices, ranging from $ICC_{(2,2)}$ = 0.83 to 0.98 for UG measurements, and 0.85 to 0.99 for GG measurements ,respectively.

Within-session inter-rater reliability (Table 3) ranged from high to very high for both goniometric devices $ICC_{(2,2)}$ = 0.71 to 0.94 for UG measurements, and 0.85 to 0.96 for GG measurements. However, only UG measurements for cervical extension had very high inter-rater reliability for both sessions. In contrast with GG measurements, all measurements had very high inter-rater reliability with the only exception for cervical flexion measured on session 2.

Coefficients of variation (CV) results for measurements of ACROM obtained by two raters with two devices are shown in Table 4 and figure 3. The CV was lowest for rater 1 in measuring cervical flexion obtained with both devices, and highest for rater 2 in measuring cervical left lateral flexion obtained with both devices.

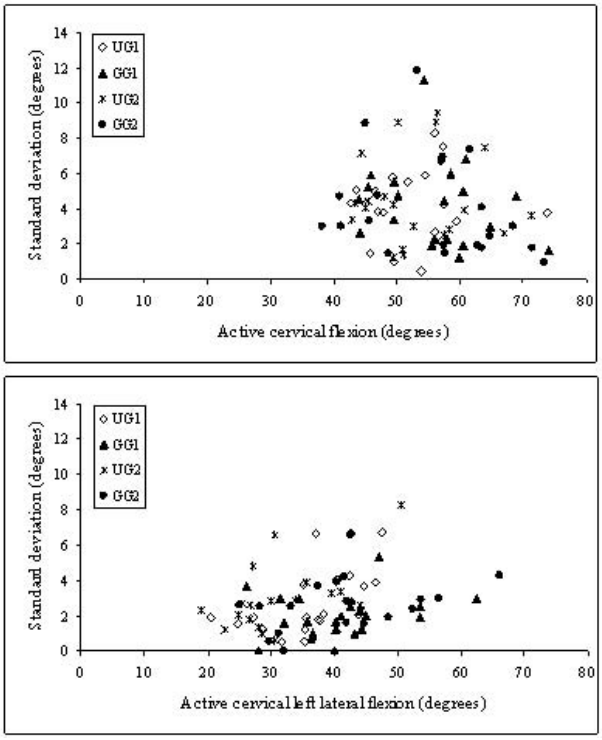


Fig.3: *Coefficient variation for measurement cervical flexion and left lateral flexion. UG1, UG2 = universal goniometer, rater 1 and 2, GG1, GG2 = invented gravity goniometer, rater 1 and 2*

4. DISCUSSION

The UG used in this study was a standard-frequent used tool in the clinical setting. Intraclass correlation coefficients $ICC_{(2,2)}$ of measurements of ACROM obtained with the UG were between high and very high rater reliability with only exception of moderate inter-rater reliability for test session 1 in measuring cervical left lateral flexion (ICC = 0.71), although ROM of this motion in both test sessions were not significantly different in degrees. The GG used in this study was invented with aimed for easy used and inexpensive tool and therefore can be alternatively choice of measuring ACROM in the clinical setting. This study demonstrated that measuring a set sequence of four ACROM had high to very high intra- and inter-rater reliability in both test sessions. The ICCs for the measurement obtained with the GG were higher than those obtained with the UG though statistical analysis was not performed in this study. Agarwal et al [4] suggest that re-measuring within same day result in higher reliability and less error compared to re-measuring between days. This study found intra- and inter-rater of re-measuring between same day and within 2 weeks were inconsistency. With the exception for inter-rater reliability for GG measurement of cervical flexion, other ACROM had higher inter-rater reliability in test session 2. Only inter-rater reliability UG measurement for right and left lateral flexion had higher inter-rater reliability in test session 2. Factors influencing reliability of the ACROM measurement may be accounted by variation among

Table 1: *Descriptive statistics for active cervical range of motion (ACROM) (n = 20)*

Motion	Range of motion (degrees)			
Device	Session 1		Session 2	
Rater	Mean±SD	Range	Mean±SD	Range
Flexion				
UG1 Trial1	49.25±7.89*	36-70	51.75±7.85	40-73
Trial2	54.15±8.03*	45-73	53.00±8.82	40-79
UG2 Trial1	51.75±7.96*	38-66	52.60±10.69	34-74
Trial2	54.50±9.08*	40-72	53.95±8.86	40-74
GG1 Trial1	52.95±9.08*	38-74	56.30±8.35	44-74
Trial2	56.40±9.10*	43-72	57.95±9.54	38-76
Flexion				
GG2 Trial1	52.05±12.41*	33-74	57.70±10.23	39-73
Trial2	56.55±11.54*	37-72	57.50±10.18	37-74
Extension				
UG1 Trial1	56.30±12.30	35-80	56.75±12.84	34-85
Trial2	53.90±12.56	30-80	56.05±12.66	33-85
UG2 Trial1	56.05±14.58	34-90	55.75±13.70	39-90
Trial2	55.50±14.62	32-87	55.45±13.86	39-85
GG1 Trial1	63.65±15.26	32-90	65.00±13.42	36-88
Trial2	63.55±13.78	28-86	65.05±13.41	40-82
GG2 Trial1	62.80±13.48	30-80	64.65±12.99	40-86
Trial2	63.10±13.81	33-81	64.55±12.85	44-86
Right lateral flexion				
UG1 Trial1	35.05±9.54	12-54	36.10±8.93	18-52
Trial2**	35.75±9.26	14-54	37.10±8.58	17-51
UG2 Trial1	29.70±7.50	15-42	31.60±7.72	14-44
Trial2**	30.50±7.92	19-46	32.70±7.97	20-44
GG1 Trial1	41.95±7.84	28-54	42.55±8.60	26-56
Trial2	42.95±8.96	25-58	43.15±8.68	26-56
GG2 Trial1	41.45±7.70*	26-52	42.05±9.05	26-56
Trial2	43.05±8.65*	26-56	42.45±8.58	26-55
Left lateral flexion				
UG1 Trial1	35.95±7.9	52-22	36.80±8.28	52-18
Trial2	35.95±6.78	45-20	37.75±8.37	55-22
UG2 Trial1	32.00±9.66	52-17	33.15±8.72	50-17
Trial2	33.10±9.75	60-21	31.50±6.91	42-21
GG1 Trial1	40.35±8.43	60-28	41.55±9.97	66-22
Trial2	40.60±8.10	60-28	41.75±9.92	64-24
GG2 Trial1	41.00±10.40	66-22	41.10±11.31	70-28
Trial2	41.65±10.00	60-24	41.60±11.10	68-25

UG1, UG2 = universal goniometer, rater 1 and 2
GG1, GG2 = invented gravitation goniometer, rater 1 and 2
*significance difference between trials for same rater and same device calculated by paired t-test at $p < 0.05$
**significance difference between raters for same device and same test session calculated by paired t-test at $p < 0.05$

the raters and uses of devices though intra-rater reliability was high to very high. The CV of raters in measuring ACROM demonstrated variation of performance among the raters. For measurements with both devices, rater 2 seemed to be the most vary (figure 3). The study suggests that providing consistent instruction and set up for the measurement would help in reducing variation among the raters and yet the rater reliability would be even higher.

5. CONCLUSION

Rater reliability in measuring a set sequence of four ACROM obtained with the UG and GG in this study has shown to be reliable. The intra-rater reliability of measurements obtained with both devices were high to very high for both raters. This study suggests that the GG measurement may be more advantage to UG measurement for assessing four ACROM in clinical setting. This is due to the high reliability and easier measurement procedures. To achieve the

Table 2: *Intra-rater reliability results for the two raters using the UG and UG devices to measure ACROM*

Motion	Device Rater	Within session intra-rater $ICC_{(2,2)}$ Session 1	Within session intra-rater $ICC_{(2,2)}$ Session 2	Between session intra-rater $ICC_{(2,2)}$
Flexion	UG T1	0.8	0.91	0.87
	T2	0.85	0.91	0.83
	GG T1	0.9	0.92	0.85
	T2	0.92	0.97	0.9
Extension	UG T1	0.94	0.96	0.94
	T2	0.99	0.98	0.98
	GG T1	0.96	0.97	0.97
	T2	0.96	0.99	0.96
Right lateral flexion	UG T1	0.98	0.95	0.94
	T2	0.92	0.96	0.93
	GG T1	0.97	0.97	0.99
	T2	0.97	0.98	0.95
Left lateral flexion	UG T1	0.94	0.93	0.9
	T2	0.96	0.93	0.93
	GG T1	0.99	0.99	0.96
	T2	0.96	0.98	0.96

UG = universal goniometer, GG = invented gravity goniometer, T1 = rater 1, T2 = rater 2

Table 3: *Inter-rater reliability between the two raters using the UG and UG devices to measure ACROM on each sessions*

Motion	Device	$ICC_{(2,2)}$ Session 1	$ICC_{(2,2)}$ Session 2
Flexion	UG	0.83	0.77
	GG	0.94	0.85
Extension	UG	0.94	0.94
	GG	0.9	0.96
Right lateral flexion	UG	0.78	0.81
	GG	0.91	0.94
Left lateral flexion	UG	0.71	0.76
	GG	0.94	0.96

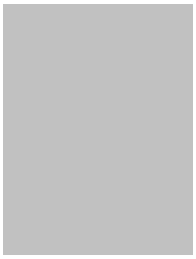
UG = universal goniometer, GG = invented gravity goniometer

Table 4: *ICoefficients of variation (CV) results for measurements of ACROM obtained by two raters with two devices*

Motion	Rater	UG (%)	GG (%)
Flexion	T1	15.77	16.18
	T2	17.09	19.94
Extension	T1	22.24	21.26
	T2	25.01	20.48
Right lateral flexion	T1	24.83	19.65
	T2	24.79	19.8
Left lateral flexion	T1	21.14	21.89
	T2	26.8	25.43

UG = universal goniometer, GG = invented gravity goniometer, T1 = rater 1, T2 = rater 2

best rater reliability of using the GG in measuring the ACROM, the instruction and location of placing the measurement scale on the subject's head must be consistent and proceed with care. Therefore, next study would be focused on the registration of manual instruction and yet study in the larger population is also necessary.



P. Manosan photograrp and biography not available at time of publication.

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