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Reliability of goniometric measurements in children with spastic cerebral palsy

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A Study Design
B Data Collection
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Summary

Background: A prospective, cross-sectional, observational study was designed to determine the reliability of goniometric measurements in children with spastic diplegic cerebral palsy (CP).

Material/Methods: The study included 38 children with spastic diplegic CP. Passive range of motion (PROM) of hip extension, abduction, and external rotation, hip flexion with knee extended, and ankle dorsi flexion was measured using universal goniometry. Each child was assessed by three physical therapists once in each session on two different sessions a week apart. Intra-test reliability was determined by paired comparison of measurements for each therapist across the two assessments. Inter-test reliability was determined by paired comparisons of the three therapists' measurements on the same session. The interclass correlation coefficient (*ICC*) was calculated for intra- and inter-test reliability.

Results: The mean absolute differences for all measures between sessions ranged from 0.10–4.86 degrees for the three physical therapists. There was no statistical significance in the mean differences between the physical therapists in all measurements ($p>0.05$) except for hip flexion with the knee extended ($p<0.05$). Inter-test reliability was high ($p<0.01$). The highest *ICC* value was 0.95 for hip extension and the lowest was 0.61 for hip abduction. Although the intra-testing reliability scores were high for all the physiotherapists, the most experienced physiotherapists' results were higher compared with the others.

Conclusions: The results from this study encourage the use of goniometric measurements in assessing children with spastic diplegic CP.

key words: **spastic diplegic cerebral palsy • goniometric measurements • passive range of motion • inter-test reliability • intra-test reliability**

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BACKGROUND

Cerebral palsy (CP) is defined as "an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of development" [1]. Spastic cerebral palsy is the most common type of CP [2]. Clinically, many different methods are used to assess spasticity in children with CP. These methods vary from subjective, ordinal, clinical scales to complex electrical or orthogenetic devices. However, these methods are not easily used clinically and mostly used in research [3–6]. Under clinical conditions, easily used methods are clinical ordinal scales and goniometric measurements that are based on the resistance to passive movement of spastic muscle and on the range of motion.

It is important to establish the reliability of goniometric measurements in children with CP as they are frequently used as a research and clinical outcome measure upon which clinical decisions are made, such as physical therapy and rehabilitation applications, orthopedic surgery, neurosurgery, and botulinum toxin injections [7,9]. Kerem et al. used goniometric measurements and the Modified Ashworth Scale to show outcomes of their study on the effectiveness of Johnstone Pressure Splints in children with spastic CP [10]. Goniometric measurements are an available and easily applied method which assesses muscle shortening and joint contracture and can also give an idea about the spasticity that is considered to limit the range of motion [11–15]. In spite of the advantages listed above, low reliability, inability to show results of treatment, and difficulty in controlling the velocity manually are some of the disadvantages of goniometric measurements. In addition, the variability of muscle tone in children with CP makes it harder to assess the range of motion (ROM) in a reliable way [16]. Studies in the literature about the reliability of goniometric measurements question the inclusion of children with different types of CP and the small numbers of children [11,13,16,21]. The purpose of the present study was to examine the intra- and -inter-test reliability of goniometric measurements in assessing the passive range of motion of the lower extremities in children with spastic diplegic CP.

MATERIAL AND METHODS

Participants

The study received ethical approval from the Hacettepe University Ethics Committee and informed consent was given by parents. A prospective, cross-sectional observational study was designed and the study included 11 girls, 27 boys, a total of 38 children with CP, and was carried out at the Hacettepe University, School of Physical Therapy and Rehabilitation, CP Unit. The mean age of the participants were 52.9±19.6 months (range: 18–108 months). Twenty children (52.6%) were at level II and 18 children (47.4%) were at level III according to the Gross Motor Classification System (GMFCS) [22].

Inclusion criteria for the study were diagnosis of spastic diplegic CP, which means with mainly lower-extremity involvement. The children were diagnosed by a pediatric neurologist and referred to our unit for a physiotherapy program. Exclusion criteria included any orthopedic surgery, botulinum toxin injection, use of an anti-spastic drug, and any rigid contractures in the lower extremities. The reason for selecting diplegic children was to try to ensure homogeneity of the subjects with a similarity of clinical types and extremity distributions.

Each child was assessed by three physical therapists once in a session in two different sessions a week apart. Intra-test reliability was determined by paired comparison of measurements by each therapist across the two assessments. Inter-test reliability was determined by paired comparisons of the three therapists' measurements on the same session. Eight of the 38 children could not participate in the second assessment session as 3 children were anxious and did not tolerate the measurement and 5 came from outside the city and were not able to attend twice. Therefore, intra-test reliability was assessed in 30 children.

Measurements

The full-time physiotherapy experience of the physiotherapists (A, B, and C) was 16, 12, and 3 years and in pediatric rehabilitation 14, 8, and 3 years, respectively. Passive range of motion (PROM) of hip extension, abduction, and external rotation, hip flexion with the knee extended, and ankle dorsi-flexion was measured by using a 360° universal goniometer. One reason for selecting these particular goniometric measurements was to indicate the tonus of the spastic muscles in hip flexors, adductors**,** internal rotators, hamstrings, and ankle plantar flexors affected in children with spastic diplegic CP. The other reason for assessing PROM in different joints was to determine whether different ranges affected reliability. A pilot study was performed to obtain agreement among the physical therapists about the measurement method and the assessments were performed by the three physical therapists (A, B, C) in the same order by using blind goniometry in a quiet room when the participants were calm and relaxed. Each physical therapist was assisted by the same fourth physical therapist, not performing any measurement but who maintained the positions of the subjects and recorded the scores.

Each child was assessed by the three physical therapists once in a session in two different sessions a week apart. Intra-test reliability was determined by paired comparison of the measurements by each therapist across the two assessments. Inter-test reliability was determined by paired comparisons of the three therapists' measurements on the same session. In a measurement session, a 30-minute interval for patients between measurements by the physical therapists was added in order to eliminate stretch reflexes occurring in the previous measurement due to the nature of spasticity and not to affect the next outcomes. The reason for the seven-day interval between the two sessions was to forget initial recordings. The participants were referred and assessed first in our unit. Pain points of the participants were taken into consideration. Discontinuations of children due to anxiety were determined as pain points.

The positions used in this study were based on those of the Stuberg's et al. [13,23]. The goniometric positioning and standardization procedures for all the measurements are shown in Table 1 [13,23,24].

Table 1. Gonimetric Positioning and standardization procedures

R.O.M Measures	Description	Extremity position	Pivot points	Stationary Arm Goniometer	Movable Arm Goniometer
Hip Extension (Thomas test)	The contralateral leg was stabilized with hip and knee flexion	Supine	Trochanter major	Parallel to long axis of trunk and CV*	Parallel to long axis of femur
Hip abduction	The contralateral leg was stabilized	Supine	S.I.A.S**	S.I.A.S**	Parallel to long axis of femur
Hip external rotation	The contralateral leg was stabilized	Sitting	Tuberositaz tibia	Parallel to floor	Parallel to crista of tibia
Hip flexion knee extended	The contralateral leg was stabilized	Supine	Trochanter major	Parallel to long axis of trunk and CV*	Parallel to long axis of femur
Ankle dorsi-flexion		Supine	Lateral malleol	Parallel to long axis of fibula	Parallel to long axis of metatarsal bones

* Columna vertebralis; ** Spina Iliaca Anterior Superior.

Statistical analysis

Mean absolute differences and *SD* values were calculated both for the intra-test and intra-test session measurements. For each measure, upper 95% confidence intervals (*CI*s) and interclass correlation coefficients (*ICC*s) were calculated. *ICC*s can vary from 0.00 to 1.00, where values of 0.60 to 0.80 are regarded as evidence of good reliability and those above indicating excellent reliability [13,18,25–27]. The parametric Student's test and ANOVA test were used to test for significant differences between physical therapists. The level of significance was set at $p<0.05$.

Results

The goniometric measurement values of the children are shown in Table 2. Mean absolute differences for all measures between sessions and significant differences between physical therapists were analyzed. There was no statistical significance except for the hip flexion with knee extended measurement ($p>0.05$) when comparing intra-sessional mean absolute differences between physical therapists. The difference was caused by physical therapist A. The mean differences were 1.21±5.92, 0.98±9.57, and 4.86±10.95 for physical therapists A, B, and C, respectively (Table 3).

Inter-test reliability was statistically significant between the three physiotherapists ($p<0.01$). Hip extension at the first measurement had the highest *ICC* values (0.95), while the second abduction measurement had the lowest (0.61). Table 4 presents *ICC*, *CI*, the Pearson correlation coefficient, and the one-way variance analysis statistic for inter-test reliability.

Intra-test reliability was statistically significant between the measurements by each physiotherapist ($p<0.01$). The hip extension measurements of physiotherapist B had the highest *ICC* value (0.99), while the hip abduction measurement by physiotherapist B had the lowest *ICC* values (0.48). Table 5 presents *ICC*, *CI*, the Pearson correlation coefficient, and one-way variance analysis statistic for intra-test reliability.

Discussion

Some authors have reported low reliability of goniometric measurements in CP [11,13,17]. In this study, the reliability of goniometric measurements in assessing PROM in the lower extremities in children with spastic diplegic CP was investigated.

Allison et al. (1996) reported that the patient should be positioned appropriately and as relaxed as possible in order to minimize external factors during measurement of goniometry [28]. The low variability and unexpectedly high reliability results of our study could be explained by the standardization of the measurement method in the pilot study, the ease of finding pivot points in children, assistance by the same physical therapist, appropriate positioning, and the experience of the therapists in goniometric measurements. In Turkey, the goniometric measurement technique is taught during graduate study at physical therapy schools in the "Assessment and Measurement" class as well as all three physical therapist attended "Assessment in Pediatric Rehabilitation" in their master of science programs, and they all had clinical experience of goniometric measurements.

Rothstein et al. (1983) reported that the mean values of many measurements would increase reliability [18]. However, due to nature of spasticity, the velocity and force of stretching could affect the severity of spasticity in the next measurement, so in our study the assessments were performed by avoiding fast stretching once and in two sessions on different days.

As measurement of hip extension is difficult due to pelvis and lumbar region mobility, the Thomas test was used instead of the hip extension measurement in the prone position [13]. In this study, hip extension measurements for intra- and inter-test reliability were high. These results were in accord with those of Stuberg et al. (1988), although they contradicted those of Bartlett et al. (1985) [13,24].

Hip abduction and hip external rotation measurements were statistically significant for intra- and inter-test reliabil-

Table 2. Goniometric Measurement Values.

Measurement		Physiotherapist	n	X	SD
Hip Extension	First	A	76	179.16	2.78
		B	76	179.03	3.11
		C	76	179.25	2.48
	Second	A	60	179.27	2.39
		B	60	179.03	2.96
		C	60	179.58	1.68
Hip Abduction	First	A	76	43.45	7.51
		B	76	43.26	6.77
		C	76	43.83	6.49
	Second	A	60	43.32	7.10
		B	60	42.18	7.66
		C	60	42.37	5.72
Hip External Rotation	First	A	76	53.28	9.56
		B	76	50.47	9.83
		C	76	52.05	10.08
	Second	A	60	54.65	9.06
		B	60	51.62	11.24
		C	60	53.90	10.32
Hip Flexion with knee extended	First	B	76	75.88	9.29
		C	76	77.96	10.92
	Second	A	60	77.37	7.62
		B	60	73.92	9.15
		C	60	72.62	9.11
Dorsi-flexion	First	A	76	97.51	10.30
		B	76	96.91	11.05
		C	76	101.13	9.68
	Second	A	60	96.82	8.98
		B	60	95.38	9.68
		C	60	99.37	8.62

n – number of participants; X – mean values; SD – standart deviation.

Table 3. Variation in intra-sessional mean absolute differences for all measures and significant differences between physical therapists.

R.O.M (n=60)	PT A Mean ±SD (Min–Max)		PT B Mean ±SD (Min–Max)		PT C Mean ±SD (Min–Max)		ANOVA
Hip extension	0.26±1.49	0–8	0.10±0.57	0–2	0.33±1.89	0–10	p>0.05
Hip abduction	0.26±6.97	0–16	0.40±8.41	0–20	1.33±5.61	0–17	p>0.05
Hip external rotation	1.26±6.73	0–20	1.25±7.92	0–20	1.98±8.33	0–20	p>0.05
Hip flexion with knee extended	1.21±5.92	0–14	0.98±9.57	0–24	4.86±10.95	0–28	p<0.05*
Dorsi-flexion	0.93±5.76	0–20	0.28±8.12	0–24	1.16±7.06	0–17	p>0.05

PT – Physical Therapist; SD – Standard Deviation; Min – Minimum; Max – Maximum; ANOVA – non-parametric analyses of variance.

Table 4. Inter-test reliability of goniometric measurements.

Measurement		PT	n	r	ICC 1	95%CI	F	p
Hip Extension	First	A–B	76	0.92	0.95	0.97	20.72	<0.01
		A–C	76	0.76				
		B–C	76	0.94				
	Second	A–B	60	0.92	0.92	0.94	12.46	<0.01
		A–C	60	0.77				
		B–C	60	0.84				
Hip Abduction	First	A–B	76	0.49	0.77	0.85	4.38	<0.01
		A–C	76	0.53				
		B–C	76	0.58				
	Second	A–B	60	0.17	0.61	0.76	2.56	<0.01
		A–C	60	0.29				
		B–C	60	0.62				
Hip External Rotation	First	A–B	76	0.79	0.91	0.94	10.72	<0.01
		A–C	76	0.69				
		B–C	76	0.81				
	Second	A–B	60	0.77	0.92	0.95	13.00	<0.01
		A–C	60	0.79				
		B–C	60	0.87				
Straight Leg Raising	First	A–B	76	0.59	0.83	0.89	5.96	<0.01
		A–C	76	0.67				
		B–C	76	0.63				
	Second	A–B	60	0.44	0.77	0.86	4.42	<0.01
		A–C	60	0.52				
		B–C	60	0.63				
Dorsi-lexion	First	A–B	76	0.71	0.88	0.92	8.67	<0.01
		A–C	76	0.75				
		B–C	76	0.71				
	Second	A–B	60	0.74	0.88	0.92	8.34	<0.01
		A–C	60	0.65				
		B–C	60	0.73				

n – number of participants; r – Pearson correlation coefficient; CI – Confidence interval; ICC1 – Intraclass Correlation Coefficient; F – one-way variance analysis statistic.

ity, although the reliability of hip abduction was the lowest compared with the other measurements. Youdas et al. (1991) reported that lack of reliability of a joint was based mostly on the wrong selection of the pivot point by the physical therapist [29]. Although we tried to prevent compensatory movements, pelvis rotation in hip abduction as well as any error in the goniometric pivot point, stationary arm, movable arm, beginning position, alignment, and velocity of movement are thought to be the factors lowering the reliability.

In the measurement of hip flexion with knee extended, the end point criterion in the study by Stuberg et al. (1988) was hip alignment [13], while in our study, ipsi lateral knee flexion was added and the contralateral leg was stabilized in extension. Intra- and inter-test reliability were high for this movement.

The measurements of the ankle dorsi-flexion movement were statistically significant for inter- and intra-test reliability and the measurements by A were higher (intra-test re-

Table 5. Intra-test reliability of goniometric measurements.

Measurement		PT	n	r	ICC 2	95%CI	F	p
Hip Extension	1–2	A	60	0.88	0.92	0.95	12.54	<0.01
		B	60	0.99	0.99	0.99	116.90	<0.01
		C	60	0.61	0.73	0.84	3.67	<0.01
Hip Abduction	1–2	A	60	0.54	0.70	0.82	3.30	<0.01
		B	60	0.32	0.48	0.69	1.93	<0.01
		C	60	0.53	0.69	0.81	3.22	<0.01
Hip External Rotation	1–2	A	60	0.75	0.85	0.91	6.79	<0.01
		B	60	0.72	0.84	0.90	6.10	<0.01
		C	60	0.67	0.80	0.88	5.07	<0.01
Hip Flexion with knee ext.	1–2	A	60	0.77	0.86	0.92	7.09	<0.01
		B	60	0.48	0.65	0.79	2.82	<0.01
		C	60	0.44	0.60	0.76	2.51	<0.01
Dorsi-flexion	1–2	A	60	0.81	0.90	0.94	9.68	<0.01
		B	60	0.69	0.81	0.89	5.38	<0.01
		C	60	0.73	0.83	0.90	5.87	<0.01

n – number of participants; r – Pearson correlation coefficient; CI – Confidence interval; ICC2 – Intraclass Correlation Coefficient; F – One-way variance analysis statistic.

liability) compared with the others and considered to be based on the greater experience of physical therapist A in pediatric rehabilitation.

Stuberg et al. (1988) assessed the reliability of five lower-extremity goniometric measurements in 20 patients with moderate to severe hypertonicity by three physical therapists and pointed out that intra-test was less than inter-test variation for all measurements; the results of our study were similar to this study. In addition, 0–28 degree variations in inter-test measurement were found, but 10–15 degrees in the Stuberg et al. study [13]. We point out the lowest (0) degree variation although our upper degree was higher than in the Stuberg study.

There was no statistical significance except for the hip flexion with knee extended measurement ($p>0.05$) among the inter-session mean absolute differences between physical therapists, and this result can be a strong aspect of our study. The difference was caused by physical therapist A. The mean differences were 1.21±5.92, 0.98±9.57, and 4.86±10.95 for physical therapists A, B, and C, respectively. McDowell and et al. (2000) reported that a further source of variability; for the biarticular hamstrings there existed between occasions a ±18–28 intra-day error (within 95% confidence limits) in their study [16]. In our study, 5.92±10.95 degrees was found and we assume the highest measurement error could be due to the difficulty in measuring the biarticular joint.

In our study, inter-test reliability had the highest *ICC* values in hip extension (0.95) and the lowest in hip abduction (0.61), while intra-test reliability had the highest *ICC* values in measurements of physiotherapist B in dorsi-flexion (0.99) and the lowest in hip abduction by the same physical therapist (0.48). Kilgour et al. (2003) investigated lower-limb range of motion (Thomas test, Staheli test, knee extension) in 25 children with spastic diplegic CP. They found inter-test *ICC* values between 0.55-0-89 and intra-test *ICC* values between 0.17–0.97 [30]. Our results are in accord with these study results.

Conclusions

Both experience and consistency play a role in goniometric reliability. The results of this study in children with spastic diplegic CP indicate that goniometric measurement is reliable for use in the clinic and also require further reliability studies in children with spastic hemiplegic and quadriplegic CP.

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