Reliability of Popliteal Angle Measurement

A Study in Cerebral Palsy Patients and Healthy Controls

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Abstract: The popliteal angle is a widely used clinical measure for hamstring contracture in cerebral palsy (CP) patients and in healthy individuals. The reliability of popliteal angle measurement is being questioned. The aim of this study is to determine the reliability of popliteal angle measurement by means of visual and goniometric assessment.

Methods: Three different observers measured the popliteal angle in 15 CP patients and 15 healthy volunteers. In each subject, popliteal angles were visually estimated and measured with a blinded goniometer twice by all observers with approximately 1 hour between measurement sessions.

Results: All intraclass correlation coefficients (ICCs) were lower in the CP group compared with healthy controls. The ICC for intraobserver differences was higher than 0.75 for both groups. The ICC for interobserver reliability of visual estimates and goniometric measurements was low for both groups. Intermethod ICC was higher than 0.75 for both groups.

Conclusions: Measurements in the CP group seemed to be less reliable than measurements in the control group. Intraobserver reliability is reasonable for both groups, but lower in CP patients than in controls. Interobserver reliability of both visual estimates and goniometrical measurements is poor. No significant differences in reliability have been found between visual estimation and goniometric measurement. Because of poor interobserver reliability of popliteal angle measurement, this should not be the only variable in clinical decision making in CP patients.

Key Words: reliability, cerebral palsy, popliteal angle, visual estimation, goniometric measurement

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Cerebral palsy (CP), a developmental disorder of movement and posture, is the most common motor impairment in children. It is caused by lesions in the fetal or infant brain, which can lead to muscle spasticity.[1,2]

Muscle spasticity may cause disorders in posture and gait. When spasticity of the hamstring muscles is present, a flexed knee gait may arise. This so-called "crouch gait" leads to a reduced range of motion of the hip and knee and increased energy consumption during ambulation.[3,4]

The popliteal angle is a measure for hamstring contracture in CP patients and in healthy individuals. It is a widely used clinical measure.[5,6] In addition, it is used as an outcome measure after medical intervention.[5–9] In CP patients with crouch gait, the decision for treatment is based for the most part on goniometric measurement of the popliteal angle.[7–10] A popliteal angle more than 45 degrees in CP patients with gait disturbance is one of the indications for hamstring-lengthening surgery.[10] This intervention seems to be an effective way to improve the gait pattern of CP patients suffering from reduced hamstring length.[8,10–12]

Results of interventions such as hamstring-lengthening surgery are irreversible. Serious complications such as genu recurvatum and muscle weakness may arise.[8,12,13] Therefore, it is important to perform surgery only when there is a clear indication. Because results of popliteal angle measurement have serious clinical consequences, it is important for this method to be reliable.

However, the reliability of popliteal angle measurement is being questioned by several authors.[9,14–16] No article has been published dealing only with this topic. Most studies assess the reliability of a wide range of goniometric measurements in CP patients. In all studies, 2 or more observers performed 2 measurement sessions in a group of CP patients. The results of these studies show high intraobserver and interobserver variation in popliteal angle measurements.[9,15–17] Most variability of measurements in CP children was observer related.[9] One study found that both intraobserver and interobserver reliability of popliteal angle measurement seem to be low, although in general, intraobserver reliability was found to be higher than interobserver reliability.[9,15,16] In addition, performing goniometric measurements may be more difficult in CP patients than in healthy controls, thereby influencing the reliability of popliteal angle measurement in a negative way. One of the studies also features a group of healthy age-matched controls. In addition, in these healthy controls, the reliability of popliteal angle measurement seems to be low.[15]

Clinicians sometimes have a tendency to estimate popliteal angles visually, rather than perform goniometric measurements. Although 1 study has indicated that there is not much difference between visual estimates and goniometric measurements in the ankle joint,[18] it has also been demonstrated by several authors that visual estimation of

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range-of-motion measurements is an imprecise and unreliable way of testing.[19–21] Because the popliteal angle is still a frequently used clinical method of assessing hamstring contractures in CP patients, it was decided to investigate its reliability more specifically.

The aim of this study was to evaluate the intraobserver and interobserver reliability of popliteal angle measurement by visual estimation and by means of a goniometer.

METHODS

Procedure

In this study, 3 different observers assessed 15 CP patients and 15 healthy volunteers. In each subject, the popliteal angles were visually estimated and goniometrically measured twice by all 3 observers with approximately 1 hour in-between measurements. A blinded standard Perspex goniometer with a 2-degree calibration was used. The goniometer was blinded on 1 side to be able to read the joint angle on the other side. Only measurements of the right leg were used in this study.

Following is the protocol for popliteal angle measurement used in this study.

The patients were in a supine position with a normal resting lordosis. Both hips were fully extended. The ipsilateral hip was flexed at 90 degrees. The knee was extended until the next end point of resistance was felt.[2] To eliminate possible initial muscle stiffness, the extension of the ipsilateral knee was performed 3 times before taking measurements. When the contralateral hip flexed as a result of the knee extension in the ipsilateral leg, the popliteal angle was visually estimated by the 3 observers (J.H., P.M., and K.M.) independently. Afterwards, with the knee still in the same position, a blinded goniometer was placed over the joint by a fourth observer (S.B.), with the blinded side toward the observers. Thus, the observers were blinded for their own goniometric measurement results. The axis hinge of the goniometer was placed on the lateral femoral epicondyle. The legs of the goniometer pointed to the trochanter major and the lateral malleolus. The observers instructed the fourth observer on how to place the goniometer. If the observers were satisfied, the fourth observer read the goniometer after its removal from the joint. The goniometric value was recorded. The 3 observers were neither not informed about the results of visual estimation of their colleagues nor about their colleagues' goniometric values. The second measurement session, which took place 1 hour later, was performed in exactly the same way. All the measurements took place in standard children's examination rooms of the outpatients' rehabilitation clinic.

Subjects

Informed consent was obtained from all subjects before testing, and the medical ethics committee approved the study protocol.

The CP group consisted of 10 boys and 5 girls, including 3 unilateral and 12 bilaterally involved children. Gross Motor Function Classification System[22] levels varied from II to V. Six children were classified as level II, 3 children matched criteria for level III, 3 were classified as level IV, and 3 fitted in the level V group. None of the subjects were undergoing any intervention other than orthotics and physical therapy at the time the measurements were performed. Four patients received botulinum toxin treatments earlier, 2 patients suffered from hip subluxation, and 3 patients had undergone previous surgery to the lower extremities. All CP patients included in this study were visiting the outpatients' rehabilitation clinic for an annual control.

To assess whether popliteal angle measurement would be more complicated in CP patients than in other subjects, we added a control group. This control group consisted of 15 able-bodied volunteers, 6 boys and 9 girls. Exclusion criteria were extreme hamstring elasticity and any history of injury or orthopedic surgery to hip or knees. Age characteristics for both groups are listed in Table 1.

Observers

The observers (J.H., P.M., and K.M.) are all members of the CP treatment team of the University Medical Centre Groningen. The team members who participated in this study were a rehabilitation physician (K.M.), an orthopaedic surgeon (P.M.), and a kinesiologist (J.H.). All observers were accustomed with the protocol used in this study. Before starting the study, they received oral and written instructions on the measurement protocol. The observers performed all measurements in the same order so that interobserver differences that are due to repeated stretching of the hamstrings can be accounted for.

Statistical Analysis

All data were analyzed with SPSS version 12.0. Variance components for main effects and 2-way interactions were calculated. Negative variance components were set to 0. From these variance components, ICCs were calculated. For a reliable measurement, an ICC should at least be 0.75. An ICC is a specific measure for reliability. For example, the intermethod ICC is a measure for the reliability of popliteal angle assessments if the assessment is performed visually and the next time by means of goniometric measurement. The intermethod ICC reflects the reliability between assessment methods. Likewise, the intraobserver ICC reflects the reliability within the observers, and the interobserver ICC reflects the reliability between observers.

The overall ICC is the overall reliability, meaning the reliability between 1 assessment, visually, by 1 observer in 1 session and another assessment by means of a goniometric measurement performed by another observer in another session. The overall ICC is calculated as a ratio. The numerator contains the variance due to subjects, and the

TABLE 1. Age Characteristics of CP and Control Group

	CP	Control
Mean age	9	23.1
Median age	7.8	21
Range	2–17	20–29

TABLE 2. Mean and SD of the Popliteal Angle of Visual Estimation and Goniometric Measurements Over Both Sessions for CP and Control Groups for the Separate Observers

	CP Group		Control Group	
	Visual Estimation, Mean (SD)	Goniometric Measurement, Mean (SD)	Visual Estimation, Mean (SD)	Goniometric Measurement, Mean (SD)
Observer 1	53.5 (19.5)	50.0 (15.2)	29.7 (15.2)	28.6 (12.9)
Observer 2	51.3 (18.8)	54.9 (17.9)	26.0 (11.2)	36.7 (12.4)
Observer 3	45.0 (20.0)	44.3 (13.8)	14.7 (11.0)	16.4 (11.8)

denominator contains the variance due to subjects, due to interactions between subject and method, subject and observer and subject and session, and the residual variance.[23]

RESULTS

Mean and standard deviation of the popliteal angle over both sessions of visual estimation and goniometric measurements for CP group and control group for the separate observers are summarized in Table 2. The mean values of observer 3 were considerably smaller compared with those of observers 1 and 2. Mean popliteal angles were smaller in the control group.

Table 3 shows the proportion of variation due to each variable and the 2-way interactions. The lower part of the table shows the ICCs. Most of the variance in measurement results can be attributed to subjects (0.62 for the CP patients and 0.44 for the control group). The error variance was calculated as the sum of the variance components minus the subject variance. Most of the error variance in popliteal angle measurement can be attributed to observer (0.12 for the CP patients and 0.24 for the control group) and subject-observer interaction (0.27 for the CP patients and 0.16 for the control group) and the residual variance (0.51 for the CP patients and 0.16 for the control group). The variance due to session and method was only a small proportion of the error variance in popliteal angle measurement. In the CP group, the variable session explained 0.02 of the error variance, and subject session interaction explained 0.05 of the total error variance. The interobserver reliability in both groups did not reach the

TABLE 3. Variance Components, Proportion of Variance, Proportion of Error Variance, and ICC of Popliteal Angle Measurements

	CP			Controls		
	Variance Components	Proportion of Variance	Proportion of Error Variance	Variance Components	Proportion of Variance	Proportion of Error Variance
Subject	210.366	0.62	—	106.036	0.44	—
Observer	16.155	0.05	0.12	56.921	0.24	0.42
Session	2.024	0.01	0.02	0*	0.00	0.00
Method	0*	0.00	0.00	0.757	0.00	0.01
Subject × observer	35.427	0.10	0.27	21.541	0.09	0.16
Subject × session	6.666	0.02	0.05	5.777	0.02	0.04
Subject × method	0.793	0.00	0.01	0*	0.00	0.00
Observer × session	0*	0.00	0.00	10.49	0.04	0.08
Observer × method	2.067	0.01	0.02	18.093	0.07	0.13
Session × method	0*	0.00	0.00	0.208	0.00	0.00
Residual variance	66.599	0.20	0.51	21.922	0.09	0.16
Sum	340.097	—	—	241.745	—	—
Sum − subject variance	129.731	—	—	135.709	—	—
	ICC			ICC		
Interobserver	0.681	—	—	0.720	—	—
Intraobserver	0.771	—	—	0.822	—	—
Intermethod	0.792	—	—	0.926	—	—
Overall ICC	0.658	—	—	0.683	—	—

*Negative variance components have been set to 0. Residual variance is the variance that cannot be attributed to the other sources of variance (subject, observer, session and method, and their 2-way interactions) Proportion of variance is calculated as the variance attributed to that specific source of variation divided by the sum of all variance components. Proportion of error variance is calculated as the variance attributed to that specific source of variation divided by the sum of all variance components minus the variance attributed to subject.

criterion for sufficient reliability. In addition, the overall ICC did not reach this criterion. All ICCs were lower in the CP group compared with those of the control group.

DISCUSSION

Popliteal angle measurement is a widely used clinical measure of hamstring contracture.[5,6] In CP patients, it is used as one of the effect measures for hamstring-lengthening surgery.[4,8] In the multidisciplinary setting of a CP treatment team, team members have to rely on their colleagues' examination results. Therefore, it is essential that team members get similar results in the case of performing popliteal angle measurements.

In this study, intraobserver reliability of popliteal angle measurement was reasonable. Intraobserver ICCs were high for visual estimates and goniometric measurements in both groups.

Interobserver reliability of popliteal angle measurement was too low. Intraclass correlation coefficients in both groups were less than the cut-off point. Other authors also concluded that most variability of measurements in CP children was observer related,[9] and that in general, interobserver reliability of goniometric measurements is low.[9,15,16,24] In this study, results show that observer 3 consequently measured smaller popliteal angles than his colleagues. Because the third observer was always the last person to perform measurements on subjects, and because repetitive measurements on the same day may reduce muscle stiffness, this finding might be explained by muscle stretching.[25] Repeated hamstring stretching leads to increased hamstring extensibility[25] and, subsequently, to smaller popliteal angles. In addition, difference in muscle strength of different observers may also lead to interobserver variation in measurement results.[19]

As expected, popliteal angles were larger in the CP group. This finding can be explained by the hamstring spasticity that is present in these patients.[5,6]

However, overall ICCs for both visual estimates and goniometric measurements are lower in the CP group than in controls, indicating lower reliability of popliteal angle measurement in CP patients. Some authors state that goniometric measurements can be more difficult in CP children, causing a decline in the reliability of measurement results.[15,16,26] The results of this study correspond with these findings. The current results show that in the CP group, a major part of the variance is bound to subject-observer interaction. A possible explanation of the difference in reliability between CP patients and controls may be that CP patients are more difficult to examine than the healthy adult controls. There were 6 patients in the CP group with a GMFCS level of IV or more. Because of their severe handicap, these patients were not able to cooperate very well with the examination (some patients were crying and protesting at the moment of testing, making it difficult to position them on the examination table). To enhance reliability of range-of-motion measurement, correct positioning of patients is essential.[19,20,27,28] Therefore, it is possible that reliability of popliteal angle measurement will be higher when the patients are more cooperative.[29] However, in this study, young CP patients were compared with an adult control group. Because young children are generally more difficult to examine, the difference in reliability of popliteal angle measurement between both groups might be caused by the age difference between the groups and the CP pathology.

In visual estimation, measurement results were often multiples of 5 or 10. However, mean and standard deviation did not differ very much from results of goniometric measurement. Intraclass correlation coefficients for both CP and control groups were greater than the cutoff point. This indicates little difference in average measurement results between visual estimation and goniometric measurement of the popliteal angle. Other authors have also found a minimal difference in average measurement results of both methods.[18]

In summary, intraobserver reliability of the popliteal angle is good for both CP patients and controls. Interobserver reliability is low for both groups. Intermethod reliability was good for healthy controls and reasonable for CP patients. All ICCs were lower in CP patients than in the control group.

Because of low interobserver reliability of popliteal angle measurements in CP patients, the popliteal angle should not be the only variable in clinical decision making in CP patients. When assessing a CP patient in a multidisciplinary setting, it is advisable to assess hamstring length with the same observer performing measurements on the patient.

REFERENCES

1. Koman LA, Smith BP, Shilt JS. Cerebral palsy. *Lancet*. 2004;363: 1619–1631.
2. Lissauer T, Clayden G. *Illustrated Textbook of Paediatrics*. London, PA: Mosby, Times International Publishers Limited; 1997.
3. Bleck EE. *Orthopedic Management of Cerebral Palsy*. London, PA: Mac Keith Press; 1987.
4. Gage JR. *Gait Analysis in Cerebral Palsy*. Oxford, PA: Blackwell Scientific; 1991.
5. Katz K, Rosenthal A, Yosipovitch Z. Normal ranges of popliteal angle in children. *J Pediatr Orthop*. 1992;12(2):229–231.
6. Reade E, Hom L, Hallum A, et al. Changes in popliteal angle measurement in infants up to one year of age. *Dev Med Child Neurol.* 1984;26:774–780.
7. Damron T, Breed AL, Roecker E. Hamstring tenotomies in cerebral palsy: long-term retrospective analysis. *J Pediatr Orthop.* 1991;11: 514–519.
8. Dhawlikar SH, Root L, Mann RL. Distal lengthening of the hamstrings in patients who have cerebral palsy. Long-term retrospective analysis. *J Bone Joint Surg Am.* 1992;74(9):1385–1391.
9. Thompson NS, Baker RJ, Cosgrove AP, et al. Relevance of the popliteal angle to hamstring length in cerebral palsy crouch gait. *J Pediatr Orthop.* 2001;21(3):383–387.
10. Rab GT. Consensus on crouched gait. In: Sussman MD, et al. *The Diplegic Child: Evaluation and Management*. Rosemont, PA: American Academy of Orthopaedic Surgeons; 1992:337–339.
11. Reimers J. Contractures of the hamstrings in spastic cerebral palsy a study of 3 methods of operative correction. *J Bone Joint Surg Br.* 1974;56:102–109.
12. Sharps CH, Clancy M, Steel HH. A long-term retrospective study of proximal hamstring release for hamstring contracture in cerebral palsy. *J Pediatr Orthop.* 1984;4:443–447.
13. Gage JR. Surgical treatment of knee dysfunction in cerebral palsy. *Clin Orthop Relat Res.* 1990;253:46–53.
14. Harris SR, Smith LH, Krukowski L. Goniometric reliability for a child with spastic quadriplegia. *J Pediatr Orthop.* 1985;5(3):348–351.
15. Kilgour G, McNair P, Stott NS. Intrarater reliability of lower limb sagittal range-of-motion measures in children with spastic diplegia. *Dev Med Child Neurol.* 2003;45(6):391–399.

16. McDowell BC, Hewitt V, Nurse A, et al. The variability of goniometric measurements in ambulatory children with spastic cerebral palsy. *Gait Posture*. 2000;12(2):114–121.
17. Fosang AL, Galea MP, McCoy AT, et al. Measures of muscle and joint performance in the lower limb of children with cerebral palsy. *Dev Med Child Neurol.* 2003;45:664–670.
18. Allington NJ, Leroy N, Doneux C. Ankle joint range of motion measurements in spastic cerebral palsy children: intraobserver and interobserver reliability and reproducibility of goniometry and visual estimation. *J Pediatr Orthop B.* 2002;11(3):236–239.
19. Dijkstra PU, Kropmans ThJB, Los H, et al. Goniometrie praktisch bekeken deel 1. *Tijdschr Fysische Ther.* 1997;1:9–15.
20. Watkins MA, Riddle DL, Lamb RL, et al. Reliability of goniometric measurements and visual estimates of knee range of motion obtained in a clinical setting. *Phys Ther*. 1991;71(2):90–95.
21. Youdas JW, Bogard CL, Suman VJ. Reliability of goniometric measurements and visual estimates of ankle joint active range of motion obtained in a clinical setting. *Arch Phys Med Rehabil.* 1993;74:1113–1118.
22. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol.* 1997;39:214–223.
23. Streiner DL, Norman GR. Content validity. In: *Health Measurement Scales: A Practical Guide to Their Development and Use*. 3rd ed. Oxford, PA: University Press; 2003:146–160.
24. Rothstein JM, Miller PJ, Roettger RF. Goniometric reliability in a clinical setting: elbow and knee measurements. *Phys Ther.* 1983;63: 1611–1615.
25. Halbertsma JPK. *Short Hamstrings and Stretching: A Study of Muscle Elasticity*. Wageningen, PA: Ponsen en Looijen; 1999.
26. Stuberg WA, Fuchs RH, Miedaner JA. Reliability of goniometric measurements of children with cerebral palsy. *Dev Med Child Neurol.* 1988;30:657–666.
27. Ekstrand J, Wiktorsson M, Oberg B, et al. Lower extremity goniometric measurements: a study to determine their reliability. *Arch Phys Med Rehabil.* 1982;63:171–175.
28. Nicol AC. Measurement of joint motion. *Clin Rehab.* 1989;3:1–9.
29. Stratford P, Agustino V, Brazeau C, et al. Reliability of joint angle measurements: a discussion of methodology issues. *Physiother Can.* 1984;36:5–9.