## Table 4. Studies on Measurement Approaches

| **Measurement of interest** | **Type of measurement tool** | **Citations** | **Level of evidence, validity and reliability** | **Position for measurement (infant and examiners)** | **Strengths and Limitations** | **What norms are used** |
| --- | --- | --- | --- | --- | --- | --- |
| **Passive side bending (S)/ lateral flexion (L)** | Arthrodial protractor | Cheng et al.1999, 2000, 2001 | Not reported for lateral flexion | Supine: 2 examiners; 1 measures and 1 stabilizes the shoulders. | S- Reproducible; used in many studies  L- no established reliability for lateral flexion | Comparison of values to right and left. |
|  | Arthrodial protractor | Ohman & Beckung, 2008 | Referenced Klackenberg’s intra rater reliability values, .94-.98 | Supine: 2 examiners; 1 measures and 1 stabilizes the shoulders. | S- Assigned PROM values. L- infants did not have torticollis | 70° mean PROM |
|  | Arthrodial protractor | Klackenberg et al. 2005 | Intra rater reliability .94 - .98 | Supine with head and body supported. PT measures; 2nd examiner stabilizes the shoulders. | S- Reproducible with high intra rater reliability L- no ICC for inter-rater reliability | ICC higher when measuring the affected side than unaffected. 60 ° infants ear reached shoulder |
|  | Goniometer with level adaptation | Karmel-Ross, 1997 | Not reported | Supine and sitting according to infant’s development. In supine the head is supported off the edge of the surface | S- assigning ROM values  L- orienting the goniometer accurately | Not reported |
|  | Photography | Klackenberg et al. 2005 | ICC (0.74-0.90) fair to good | Supine PT measures and 2nd examiner stabilizes the shoulders. Photo is taken and examiner draws on photo | S- comparison values to measurement with protractor L- Too many variables to control. Extra steps. Author reports unfeasible | Not reported |
|  | Photography | Rahlin & Sarmiento, 2010 | Intra-rater reliability .80 - .85, ICC(3,1)  Inter-rater reliability .72 - .99 ICC (2,1) | Supine. One examiner places child and provides visual stimulus in midline | S- measures the infants resting posture L- time consuming with several steps to measure the photograph . |  |
|  | Palpation of extensibility | Emery 1994 | Not reported | 2 examiners PT measures the 2nd stabilizes the shoulders | Subjective data no definition of resistance | Not reported |
| **Passive cervical rotation** | Arthrodial protractor | Cheng et al., 1999, 2000, 2001 | Inter-rater reliability ICC .71 unpublished data | Supine with the head supported off the edge of the surface; 2 examiners 1 measures and 1 stabilizes the shoulders. | S- Reproducible and used in many studies  L- unpublished data | 110° cervical rotation |
|  | Arthrodial protractor | Ohman & Beckung, 2008 | Inter-rater reliability ICC .71 per Cheng’s unpublished date | Cheng’s method | S- Assigned PROM values. L- infants did not have torticollis | 110°mean PROM |
|  | Goniometer | Klackenberg et al. 2005 | Right CMT ICC.82 - .95 for rotation and side for rotation and lateral flexion. ICC .58 - .65 for rotation and side for rotation and lateral flexion to the non-affected side | Supine with head and body on the surface. PT measures and 2nd examiner stabilizes the shoulders. | S- establishing intra-rater reliability L- cervical rotation is limited by supporting surface | ICC higher when measuring the affected side than unaffected; 70 – 80 ° when infant’s chin touches supporting surface |
|  | Goniometer with level adaptation | Karmel-Ross, 1997 | Not reported | Supported sitting according to infant’s development. 2nd examiner stabilizes shoulders | S- values can be assigned  L- accounting for compensations of trunk and shoulders | 100 – 120° cervical rotation per Emery values 1994 |
|  | Visual inspection | Boere-Boonekamp & van Der Linden-Kuiper, 2001 | Not reported | Supine | S- Easy to administer | n/a |
|  | Palpation of extensibility | Cameron | Not reported | Supine 2 examiners one measures the 2nd stabilizes the shoulders | S- Easy to administer; Subjective | Symmetry of movement by feel. Grades assigned by mild, moderate, severe. |
| **Active lateral flexion /side bending** | Muscle Function Scale | Ohman et al., 2009 | Inter and Intra rater reliability Kappa>0.9; ICC. 0.9 | Infant is held in a vertical position and lowered to horizontal | S- valid and reliable measure of lateral flexion strength L- lateral flexion only | 0 – 5 score Validated on infants > 4 months of age 5/5 is normal strength of lateral flexion |
|  | CROM Inclinometers mounted on glasses head and magnet yolk on trunk | Karmel-Ross, 1997 | Not reported | Supported sitting in adapted car seat mounted on hinge | S- measures for lateral flexion L- Stabilizing of the body. Child needs head and trunk control | Not reported |
| **Active cervical rotation** | Visual tracking | Persing 2003  Laughlin 2011 | Not reported | Supine infants < 4 months and supported sitting in examiners lap for infants > 4 months | Easy to administer but no values | -0-Comparison between right and left ranges |
|  | Visual tracking | Boere-Boonkamp 2001 | Not reported | Supine, 1 examiner to encourage the infant to track | S- Easy to administer but no values L- subjective | -0-Comparison between right and left ranges |
|  | CROM- Inclinometers mounted on glasses head and magnet yolk on trunk | Fletcher 2008 | Intra rater reliability ICC .92 for lateral flexion  ICC .94 for rotation | 1 examiner with subject independent sitting | S- reproducible if child is older and cooperative  L- Adults only head array needs to be worn | No values for infants |
|  |  | Youdas 1992 | Inter rater: ICC.80; Intra rater: ICC.67 to.90 (median=.86) for left lateral flexion,  ICC.60 to .94 (median=.85) for right lateral flexion, .81 to .95 (median=.84) for left rotation, and .58 to .99 (median=.80) for right rotation. | 1 examiner with subject independent sitting | S- reproducible if child is older and cooperative L- Adults only head array needs to be worn | No values for infants |
| **Classification reliability** | CMT Severity Classification System (7-grades) | Oledzka et al. 2018 | Inter rater reliability is good: ICC (2,1) = 0.83 [95% CI 0.74-0.91]).  Intra rater reliability is good; (ICC (3,1) = 0.81 [95% CI 0.66-0.91]) | Not applicable | S-Large sample with some attrition  L- classification grades were assigned using paper cases versus independent assessment in a clinical setting. | Not applicable |

Abbreviations: CMT, congenital muscular torticollis; CROM, cervical range of motion; ICC, intraclass correlation coefficient; L, limitation; PROM, passive range of motion; S = strength.