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Original Research

# Reliability of the EasyAngle® for Assessing Hip Range of Motion in Healthy Children

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## Background

The use of digital goniometry has emerged as a viable alternative to universal goniometry for assessing hip range of motion (ROM). However, few studies have assessed the use of digital goniometry in pediatric populations and there are a limited number of studies that investigate any one device. The EasyAngle® is a digital goniometer that may be beneficial for use in pediatric settings as it requires only one hand to operate the device.

## Purpose

The purposes of this study were 1) to establish the intrarater and interrater reliability of the EasyAngle® digital goniometer in measuring hip joint ROM in healthy elementary school-aged children, and 2) to establish preliminary normative reference values for each year of age using the EasyAngle® for hip joint ROM in healthy elementary school-aged children.

## Study Design

Descriptive Laboratory Study

## Methods

Passive hip ROM (flexion, abduction, extension, internal rotation, external rotation) was measured on each leg of healthy participants using the EasyAngle®. A total of 40 hip joints were measured. Two blinded raters conducted three trials of each hip motion on both legs. Intrarater and interrater reliability of the recorded hip range of motion were calculated using intra-class correlation coefficients (ICC) (3,1).

## Results

Twenty healthy children were measured (age 5-10, mean = 7.40 years old, SD = 1.37, 9 males, 11 females). Mean hip ROM was reported by age. Intrarater and interrater reliability were good to excellent for all hip ROM measurements (0.81-0.97 intra rater; 0.77- 0.91 interrater). Hip flexion had the strongest intrarater (0.96, 0.97) and interrater reliability (0.91). Intrarater reliability was lowest for hip abduction for Rater 1 and hip extension for Rater 2. Interrater reliability was lowest for hip external rotation (0.78)

## Conclusion

The EasyAngle® is a reliable tool for assessing hip range of motion in healthy children ages 5-10. Normative hip ROM values using the EasyAngle® are available to clinicians.

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## Level of Evidence

Level 3- Reliability study

## INTRODUCTION

Participation in team sports is an increasingly popular activity for children in the United States. Data from 2020 shows that over half of US children between the ages 6-17 participate in at least one sport throughout the year.[1] While participation in youth sports provides numerous benefits, such as improvements in grades and physical activity levels, it is also associated with an increased risk of injury. More than 3.5 million children ages 5-14 have visited the emergency room for a sports-related injury, and the majority of these injuries involve the lower extremity.[2] The preparticipation examination was developed as a preventative tool against sports-related injury, and it is recommended that a musculoskeletal examination is conducted as part of this assessment. Range of motion (ROM) is an important component of a musculoskeletal examination, for children with and without impairments. Decreased ROM may be indicative of muscular shortening, joint stiffness, spasticity, bony torsion, and many other neuromusculoskeletal impairments and injuries.[3,4] Improvements in ROM are often one of the many desired outcomes of physical therapy interventions, as improved ROM leads to improvements in activity and participation (including participation in youth sports).[3] Therefore, it is important for clinicians to have accurate and reliable methods to measure and track changes in ROM.

The universal goniometer (UG) is the preferred method for quantifying joint mobility in clinical practice. The device's relatively low cost and versatility make it a staple in most clinics today, and it has been shown to be both reliable and valid.[5] Despite its versatility, its use in particular pediatric populations is questionable. One study suggests that the UG has poor reliability for the measurement of hip ROM in pediatric femoral fractures owing partially to the children's small physical size and lack of cooperation.[6] Utilization of the UG is further complicated by its protocol for use. Two hands are needed to operate the goniometer, and the participant is required to maintain a static position or may require external stabilization (which may be difficult for pediatric participants). Furthermore, there is limited information on a standardized protocol for positioning the participant to measure ROM in pediatric populations as there is for adults.[3,4]

Alternative approaches to measuring joint ROM have begun to emerge, which include (but are not limited to) smartphone applications, digital photography, digital inclinometers, and digital goniometers. There is a growing body of literature surrounding the clinical applicability of these new methods, and overall they are reliable and valid for use on various body segments in adult populations.[7,8] Longoni et al.[7] appraised 13 different smartphone applications and reported mostly good intrarater and interrater reliability, with an ICC value of 0.80 for extremities (reliability was lower for measurements of the spine).[7] Roach et al.[9] concluded that the digital inclinometer has high intrarater reliability with an ICC value of 0.90 and is valid for measuring passive ROM of the hip. However, they also determined that the digital inclinometer does not have concurrent validity against a universal goniometer and as such, these two devices should not be used interchangeably.[9] While studies with adult populations have reported high degrees of intrarater and interrater reliability (ICC > 0.85), they also report limitations in sample size or clinical generalizability.[10] Additionally, despite ongoing research regarding alternative methods of goniometry, very few studies investigate clinical applicability in the pediatric population.

The EasyAngle®, developed by Meloq (Stockholm, Sweden), is a digital goniometer that can be used in place of UGs, inclinometers, scoliometers, cervical range of motion (CROM) devices, and back range of motion devices.[11] The manufacturer reports the device measures ROM in all three planes of movement of any given joint and is convenient for measuring ROM in the pediatric population due to its portability, clear alignment guide, and single-handed use. Current studies using the EasyAngle® in adults, while limited, have demonstrated good intrarater and interrater reliability for measuring knee, scapular, and cervical ROM. Intrarater reliability was found to be as high as an ICC value of 0.998 depending on the joint measured, while ICC values for interrater reliability were reported to be as high as 0.994. Measurements of knee ROM were consistently the highest, and scapular ROM consistently yielded the least reliable results.[12,13] Svensson et al. identified no difference between novice and experienced clinicians when using the EasyAngle®.[12] Furthermore, the EasyAngle® has been found to be comparable to or more reliable than traditional methods of measuring ROM such as inclinometry, digital photography, and CROM device use across multiple populations (either individuals with a pathology of interest or healthy individuals).[12,13] Currently, no published studies assess the use of the EasyAngle® in pediatric populations. Furthermore, there are a limited number of studies that assess the reliability of the EasyAngle® in measuring hip ROM, and none of the studies that specifically investigate the hip joint are available in English. The hip joint is of particular interest in the pediatric population as it is involved in 10-24% of youth sports-related injuries.[2]

In addition to a reliable tool to measure and track ROM, a clinician must also have access to ROM values gathered from a healthy population so that atypical values can be distinguished from reference, or "normed," values. In pediatric populations, it is important to establish age- and sex-matched norms to accurately identify deviations from typical development so that therapeutic interventions can be implemented to increase function and participation.[4,14]

The purposes of this study were 1) to establish the intrarater and interrater reliability of the EasyAngle® digital goniometer in measuring hip joint ROM in healthy elementary school-aged children, and 2) to establish preliminary normative reference values for each year of age using the EasyAngle® for hip joint ROM in healthy elementary school-aged children. To the authors' knowledge, no known studies exist that explore the reliability of hip measurements using the EasyAngle® in the pediatric population. The research question was: Is the EasyAngle® a reliable tool to measure hip range of motion in elementary school-aged children?

## METHODS

After Institutional Review Board approval, participants whose parents understood, signed, and returned both the consent and assent forms to investigators were included. Local guidelines regarding COVID-19 were followed and efforts were made to maintain social distancing when possible.

This study included 20 healthy participants - 9 male and 11 female students from a local elementary school. The right and left legs of each participant were counted separately to reach a sample size of N = 40 hip joints.[12] Inclusion criteria included both males and females who were of elementary school age (kindergarten through 4th grade) from a convenience sample. Participants were excluded if they had a diagnosed musculoskeletal condition such as a bone fracture in the leg, Osgood-Schlatter, Legg-Calve-Perthes disease, slipped capital femoral epiphysis, or muscle strain. Participants were also excluded if they had been diagnosed with a neuromuscular condition such as cerebral palsy, muscular dystrophy, or spina bifida. The school administration was aware of the exclusion criteria and assisted in the screening process. Demographic data, including age, sex, and ethnicity were collected from each participant prior to measurement.

The EasyAngle® device was used for all data collection. A team of four student physical therapists divided into two measurement teams to conduct the data collection. On each team, one researcher served as the data recorder while the other served as the rater. Teams and roles were determined prior to testing and remained consistent throughout the study. Both raters had experience with goniometric measurements. Prior to data collection at the school, all researchers underwent EasyAngle® device training with a Meloq representative. The researchers conducted two practice sessions, each lasting two hours, to familiarize themselves with the device. Members of the research team acted as "participants" during these practice sessions. Prior to initiating the study at the school, a practice session with one elementary school-aged participant was conducted to determine proper positioning and stabilization of the participant as well as placement and use of the EasyAngle®. No data was recorded from this session and therefore the measurements obtained from this participant were not included in the final data analysis. Raters were blinded to the measurements from the EasyAngle® by placing opaque tape over the device's screen. Blinding was done to prevent bias that may have occurred had the rater known each measurement after obtaining the data. Each data recorder ensured all measurements were properly collected and recorded on the EasyAngle® device.

Data were collected at the local elementary school over a period of four nonconsecutive days in June of 2022. Participants were brought into the examination room two at a time and assigned to a measurement team. Participants were informed of all measurement procedures and verbal as well as written assent was obtained. Participants were dressed in their school uniforms, which consisted of a t-shirt and either shorts or skirts and leggings. A licensed physical therapist was present to oversee the student research teams, and parents were notified via the cover letter that they were permitted to be present in the room during their child's testing session (however, no parents elected to attend data collection sessions).

### TESTING PROTOCOL

The rater conducted four trials of passive range of motion of each of the five hip motions – flexion, abduction, extension, internal rotation, and external rotation, respectively. The participant was positioned in supine for flexion and abduction, and prone for extension, internal rotation, and external rotation. Measurement for each motion was obtained first on the right lower extremity and then the left. The first trial served as a demonstration and was not recorded. For each trial in which data was recorded, the EasyAngle® was first aligned with standardized anatomic landmarks (as described in Appendix 1), and the turquoise button was pressed to indicate the start of the measurement. The limb was then passively moved into the standardized measurement position as described in Appendix 1, and the device was moved along with the limb. The turquoise button was pressed for a second time to indicate the end of the measurement.[11,12] The turquoise button was pressed for a third time to save the measurement and then pressed a fourth and final time to begin the next trial. Figure 1 depicts how the device can be used to measure hip flexion.

After the rater completed the three recorded trials of any particular hip motion, the data recorder documented the three measurements obtained, then cleared the device's history and returned the recalibrated device to the rater. Once measurements had been obtained for all five hip motions on both the right and left legs, each participant repeated the procedure with the other measurement team. Total testing time was approximately 30 minutes per participant (15 minutes per rater). Refer to Appendix 1 for a complete testing protocol that was developed for this research study.

### STATISTICAL METHODS

A preliminary power analysis was conducted based on calculations developed by Bujang and Baharum using the Power Analysis and Sample Size (PASS) software.[15] An $\alpha = 0.05$ and $\beta = 0.2$ (power = 80%) were used to determine that a minimum sample size of 36 was required for an expected ICC of 0.95 Both the intrarater and interrater reliability of the recorded hip range of motion were calculated using intra-class correlation coefficient (ICC) (3,1) using an average of three trials per hip motion and a confidence interval of 95%. The ICC values were interpreted as poor (<0.5), moderate (0.5-0.75), good (0.76-0.90), or excellent (>0.90) reliability.[16] An independent samples t-test was performed to

**Figure 1. Starting (left) and ending (right) positions for measurement of hip flexion using the EasyAngle®.**

determine if gender-based differences in hip ROM existed. The significance level was set to $p < 0.05$. Statistical assumptions were met to proceed with parametric testing. All data were analyzed using SPSS version 27 (IBM SPSS Inc, Armonk, NY, USA).

## RESULTS

### DESCRIPTIVE STATISTICS FOR HIP RANGE OF MOTION

Data were collected on 40 hip joints from 20 participants between the ages of 5-10 (mean = 7.40 years old, SD = 1.37) including nine male participants (18 hip joints) and 11 female participants (22 hip joints). There were 15 Black or African American participants, three White participants, and two Hispanic or Latino participants. Table 1 provides the mean range of motion measurements for five hip motions by age. Most of the hip joints assessed in this study were from participants who were 8 years old (N = 14 hip joints).

### COMPARISON OF HIP MEASUREMENTS BY RATER

A total of five hip range of motion measurements were recorded three times each by both raters. Table 2 illustrates the mean range of motion measurements for each rater. Overall, Rater 1 appeared to measure greater range of motion compared to Rater 2. Higher standard error values were noted for both raters with external rotation and lower standard error values were seen for both raters with hip extension.

### INTRARATER RELIABILITY OF HIP MEASUREMENTS USING THE EASYANGLE®

Intrarater reliability for all five hip range of motion measurements is presented in Table 3. The results showed good to excellent intrarater reliability for both raters [ICC (3,1) = 0.888 - 0.961, Rater 1] [ICC (3,1) = 0.807 - 0.971, Rater 2] for all hip range of motion measurements. Hip flexion had the highest ICC value for intrarater reliability [ICC (3,1) = 0.961, Rater 1 and 0.971, Rater 2]. Hip abduction had the lowest intrarater reliability for Rater 1 [ICC (3,1) = 0.888], and hip extension had the lowest intrarater reliability for Rater 2 [ICC (3,1) = 0.807].

### INTERRATER RELIABILITY OF HIP MEASUREMENTS USING THE EASY ANGLE

Interrater reliability for all five hip range of motion measurements is provided in Table 3. Both Rater 1 and Rater 2 had ICC values for interrater reliability that were considered good to excellent for all five hip range of motion values. Hip flexion had the highest ICC value [ICC (3,1) = 0.911] and hip external rotation demonstrated the lowest ICC value [ICC (3,1) = 0.778].

### INDEPENDENT SAMPLES T-TEST

An Independent Samples T-Test compared mean hip range of motion measurements between measures obtained from male and female participants as shown in Table 4. Hip flexion ($p = 0.002$) and abduction ($p = <0.001$) were statistically significantly different. The other three measures were not significantly different, but overall females demonstrated greater range of motion measurements compared to males.

**Table 1. Mean Hip Range of Motion by Age**

| | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10 |
|---|---|---|---|---|---|---|
| N | 4 | 8 | 6 | 14 | 6 | 2 |
| Flexion | 113 (79,137) | 106 (83,127) | 110 (48,128) | 106 (68,146) | 105 (86,125) | 100 (85,113) |
| Extension | 23 (17,31) | 21 (9,30) | 20 (7,31) | 20 (2,34) | 22 (6,28) | 23 (18,24) |
| Abduction | 45 (33,63) | 45 (26,72) | 45 (24,62) | 48 (24,68) | 46 (32,65) | 48 (33,59) |
| Internal Rotation | 43 (30,51) | 42 (26,57) | 43 (24,59) | 38 (21,56) | 36 (17,45) | 38 (20,55) |
| External Rotation | 38 (16,58) | 39 (19,60) | 34 (18,51) | 36 (15,59) | 39 (19,70) | 35 (28,43) |

N = number of hip joints assessed
Range of motion measured in degrees
Minimum and maximum range of motion values shown in parentheses

**Table 2. Comparison of Hip Measurements by Rater. All results are reported in degrees.**

| | | Rater 1 | | | Rater 2 | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | SE | Mean | SD | SE |
| Flexion | | | | | | | |
| | Trial 1 | 113.35 | 10.22 | 1.62 | 101.23 | 20.56 | 3.25 |
| | Trial 2 | 113.05 | 10.59 | 1.67 | 99.83 | 21.15 | 3.34 |
| | Trial 3 | 114.45 | 10.97 | 1.73 | 99.83 | 19.63 | 3.10 |
| | Mean | 113.62 | | | 100.29 | | |
| Extension | | | | | | | |
| | Trial 1 | 23.82 | 4.41 | .70 | 18.78 | 5.51 | .87 |
| | Trial 2 | 23.85 | 4.49 | .71 | 17.80 | 5.87 | .93 |
| | Trial 3 | 23.20 | 4.32 | .68 | 16.55 | 4.98 | .79 |
| | Mean | 23.63 | | | 17.71 | | |
| Abduction | | | | | | | |
| | Trial 1 | 55.25 | 8.04 | 1.27 | 37.32 | 7.40 | 1.17 |
| | Trial 2 | 56.32 | 6.62 | 1.05 | 36.77 | 7.81 | 1.24 |
| | Trial 3 | 54.20 | 7.10 | 1.12 | 38.27 | 7.74 | 1.22 |
| | Mean | 55.25 | | | 37.46 | | |
| Internal Rotation | | | | | | | |
| | Trial 1 | 43.00 | 7.40 | 1.17 | 34.38 | 9.28 | 1.47 |
| | Trial 2 | 44.07 | 6.26 | .99 | 34.55 | 8.88 | 1.40 |
| | Trial 3 | 45.75 | 6.61 | 1.05 | 35.30 | 10.40 | 1.64 |
| | Mean | 44.27 | | | 34.74 | | |
| External Rotation | | | | | | | |
| | Trial 1 | 46.90 | 1.25 | 7.88 | 27.65 | 1.11 | 7.05 |
| | Trial 2 | 46.13 | 1.33 | 8.43 | 26.78 | 1.08 | 6.80 |
| | Trial 3 | 46.78 | 1.51 | 9.53 | 28.40 | 1.16 | 7.33 |
| | Mean | 46.60 | | | 27.61 | | |

SD = Standard Deviation
SE = Standard Error

## DISCUSSION

The results of this study suggest that the EasyAngle® is a reliable tool for assessing hip joint ROM in healthy children ages 5-10. Intrarater and interrater reliability were good to excellent for all motions assessed.[16] Intrarater reliability is clinically relevant in order to determine whether or not a device consistently measures data across multiple trials for a participant while one clinician is performing the mea-

**Table 3. Interclass Correlation Coefficients for Both Raters and Between Raters**

| | ICC | 95% Confidence Lower | 95% Confidence Upper | F | Df | p-value |
|---|---|---|---|---|---|---|
| **Intrarater Reliability** | | | | | | |
| **Rater 1** | | | | | | |
| Flexion | .961 | .934 | .978 | 25.708 | 39 | <.001 |
| Extension | .907 | .843 | .948 | 10.730 | 39 | <.001 |
| Abduction | .888 | .811 | .937 | 8.943 | 39 | <.001 |
| Internal Rotation | .904 | .839 | .946 | 10.467 | 39 | <.001 |
| External Rotation | .910 | .847 | .949 | 11.054 | 39 | <.001 |
| **Rater 2** | | | | | | |
| Flexion | .971 | .950 | .984 | 34.113 | 39 | <.001 |
| Extension | .807 | .674 | .891 | 5.178 | 39 | <.001 |
| Abduction | .895 | .822 | .941 | 9.503 | 39 | <.001 |
| Internal Rotation | .855 | .755 | .918 | 6.897 | 39 | <.001 |
| External Rotation | .872 | .783 | .928 | 7.791 | 39 | <.001 |
| **Interrater Reliability** | | | | | | |
| Flexion | .911 | .861 | .948 | 11.266 | 39 | <.001 |
| Extension | .792 | .674 | .878 | 4.815 | 39 | <.001 |
| Abduction | .792 | .673 | .878 | 4.803 | 39 | <.001 |
| Internal Rotation | .819 | .716 | .894 | 5.523 | 39 | <.001 |
| External Rotation | .778 | .651 | .870 | 4.501 | 39 | <.001 |

ICC = Intraclass coefficient, F = Frequency, Df = Degrees of Freedom, p-value = Probability value

**Table 4. Independent Samples T-test for Gender and Hip ROM Measurements. Average ROM reported in degrees.**

| | Male | Female | p-value |
|---|---|---|---|
| N | 18 | 22 | .002 |
| Flexion | 100.06 | 112.59 | |
| Extension | 19.76 | 21.40 | .142 |
| Abduction | 42.56 | 49.45 | <.001 |
| Internal Rotation | 38.58 | 40.26 | .387 |
| External Rotation | 35.58 | 38.35 | .110 |

N = number of hip joints measured, p-value = Probability value.

surements. Interrater reliability is clinically relevant in order to determine whether or not a device consistently measures data between multiple raters. These findings suggest that this tool is reliable for use between therapy sessions and between clinicians, so long as standardized protocols related to positioning are established.

Based on a review of existing literature, the researchers hypothesized before initiating data collection that the EasyAngle® should be a reliable tool to measure hip ROM in the pediatric population.[12,13] While this is the first known study to evaluate the EasyAngle®'s use for assessing hip ROM in a pediatric population, previous authors who studied various adult populations suggest that the EasyAngle® is a reliable device for joints such as the knee, shoulder, and cervical spine. In this current study, both intrarater and interrater reliability were good to excellent for each motion assessed. Hip flexion had the highest intrarater reliability [ICC (3,1) = 0.961, Rater 1 and 0.971, Rater 2] and interrater reliability [ICC (3,1) = 0.911]. This may be due to the relative ease of passively performing this movement compared to others. A challenge to each motion (aside from flexion) was ensuring that measurements were taken in a straight plane without compensatory movements such as pelvic rotation. This may account for the lower intrarater reliabilities seen with abduction for Rater 1 [ICC (3,1) = 0.888] and extension for Rater 2 [ICC (3,1) = 0.807], as each rater may have determined the threshold of compensatory motion differently. Another explanation for the high ICC values seen for hip flexion is that it was the first measurement taken on each participant, so the participant may have been more engaged and better able to relax during this measurement.

In general, intrarater reliability was greater than interrater reliability, which is consistent with previous studies.[5,8] A challenge that may have contributed to lower ICC values for interrater reliability could be fatigue on the part of both

**Table 5. Comparison of Range of Motion Normative Values in Pediatric Populations (Age Measured in Years).**

| | Soucie et al., 2011 | | Mudge et al., 2014 | Sankar et al., 2012 | | Lowes & Hay, 2017 |
|---|---|---|---|---|---|---|
| | Male | Female | | Male | Female | |
| Flexion | 2-8 yrs: 131.1° | 2-8 yrs: 140.8° | | 2-5 yrs: 118° | 2-5 yrs: 121° | |
| | 9-19 yrs: 135.2° | 9-19 yrs: 134.9° | | 6-10 yrs: 118° | 6-10 yrs: 122° | |
| | | | | 11-17 yrs: 113° | 11-17 yrs: 120° | |
| Extension | 2-8 yrs: 28.3° | 2-8 yrs: 26.6° | 4-7 yrs: 15° | 2-5 yrs: 21° | 2-5 yrs: 21° | 1 yrs: 7° |
| | 9-19 yrs: 18.2° | 9-19 yrs: 20.5° | 8-11 yrs: 13° | 6-10 yrs: 19° | 6-10 yrs: 21° | 3 yrs: 7° |
| | | | 12-16 yrs: 9.1° | 11-17 yrs: 15° | 11-17 yrs: 22° | 5 yrs: 7° |
| Abduction | | | 4-7 yrs: 42.1° | 2-5 yrs: 51° | 2-5 yrs: 22° | 1 yrs: 59° |
| | | | 8-11 yrs: 36.4° | 6-10 yrs: 43° | 6-10 yrs: 39° | 3 yrs: 59° |
| | | | 12-16 yrs: 33.6° | 11-17 yrs: 34° | 11-17 yrs: 28° | 5 yrs: 54° |
| Internal Rotation | | | 4-7 yrs: 61.3° | 2-5 yrs: 45° | 2-5 yrs: 47° | 1 yrs: 38° |
| | | | 8-11 yrs: 61.2° | 6-10 yrs: 40° | 6-10 yrs: 41° | 3 yrs: 39° |
| | | | 12-16 yrs: 49.0° | 11-17 yrs: 35° | 11-17 yrs: 35° | 5 yrs: 34° |
| External Rotation | | | 4-7 yrs: 49.5° | 2-5 yrs: 51° | 2-5 yrs: 49° | 1 yrs: 58° |
| | | | 8-11 yrs: 44.1° | 6-10 yrs: 44° | 6-10 yrs: 48° | 3 yrs: 56° |
| | | | 12-16 yrs: 50.5° | 11-17 yrs: 40° | 11-17 yrs: 46° | 5 yrs: 39° |

yrs = years old

the participant and the rater. External rotation had the lowest interrater reliability [ICC (3,1) = 0.778]. However, this was the last measurement taken for each participant, so at least 12 measurements had been taken previously. At this point, participants may have been fatigued from the number of measurements obtained and may not have been as relaxed to allow for full passive range to be assessed. Conversely, there may have been fatigue on the part of the raters. Having taken a large number of measurements, each rater may have unintentionally performed less precise measurements for external rotation or may have determined that compensatory movement was occurring at an earlier point than for previous measurements. The lower interrater reliability for hip external rotation may be due to differences in determining compensatory movements or may be due to fatigue from an extensive measurement protocol.

Previous studies have compiled normative data regarding hip joint range of motion in pediatric populations based on age and sex; however, these norms were derived from early studies that utilized universal goniometry.[4] Table 5 illustrates mean ROM values for children obtained via universal goniometry from multiple studies using a variety of methods.[3,4,14,17]

The data from the current study suggest that gender was a significant factor for hip flexion and abduction. In a study by Sankar et al. researchers found that older males (ages 11-17) had less ROM than older females in all directions aside from internal rotation (combined with hip flexion); however, they found no significant difference for gender with any motion in their youngest age group (ages 2-5), and no findings regarding gender differences were discussed for ages 6-10.[17] The current study produced similar findings where ROM was greater in females compared to males; however, these findings were seen in a younger age range (5-10 years old) than identified by Sankar et al.

Statistical analysis regarding the relationship between age and ROM was omitted from this study due to a relatively small number of hip joints present in each individual age group from ages 5-10. However, the descriptive data that was obtained suggests little to no change with age across all five joint motions. This is in contrast to previous studies, which suggest that range of motion tends to decline with increasing age.[4,14,17] An important note is that the age range in this study (5-10 years old) is narrower than in previous studies, which may explain this difference in findings. A gross comparison to the norms established in previous studies (Table 5) reveals that this study produced relatively similar averages across the age group studied here. While flexion and external rotation were slightly higher in previous studies, this present study found measures of extension, abduction, and internal rotation to be fairly consistent with previously established normative data.

### LIMITATIONS

One limitation of this study is that a relatively homogenous sample was obtained. 75% of the hip joints measured were from Black or African American participants, while 15% of hip joints were from White participants and 10% were from Hispanic or Latino participants. Because of the limited diversity of participants, the findings of this study may not be applicable to children of various ethnic backgrounds. Another limitation may have been related to differences between raters in determining the endpoint of ROM. Efforts were made to minimize any discrepancy between raters through multiple practice sessions with members of the research team to gain familiarity with the device, as well as a practice session with a child not included in the study. An established protocol was followed, and feedback was provided by members of the research team during all practice sessions to promote consistency with measurements. Despite this, it is possible that each rater may have had different criteria for determining end-feel and for determining when any compensatory movements (such as pelvic rotation during hip IR/ER) began. For instance, if one rater stopped the measurement at the first point of resistance (R1) rather than moving their participant through the full available range (R2), this would result in lower range of motion measurements obtained by that rater. This may explain the differences seen in ICC values between intrarater and interrater reliability as explained previously. Another limitation of this study may have been related to participant behavior. As the number of measurements obtained required each participant to remain still for an extended period of time, there were some instances where the participant had difficulty relaxing and allowing full passive movement. Additionally, there were several times when the participant had to be asked to return to the testing position. Thus, the first rater to assess a participant may have obtained more accurate findings compared to the second rater based on behavior experienced throughout the testing session.

### FUTURE RESEARCH

As this is the first known study to date to assess the use of the EasyAngle® for measuring hip ROM in pediatric populations, it is recommended that future studies replicate this one to verify and expand upon the reliability of the results in this study, as well as to refine this original testing protocol. While this study obtained a sufficient sample size based on a preliminary power analysis, future studies with larger national sample sizes across a variety of geographic areas would help to strengthen the results. Finally, future studies are needed to investigate the reliability of the EasyAngle® in children who participate in youth sports or in children with diagnosed conditions.

## CONCLUSIONS

The results of this study suggest that the EasyAngle® is a reliable tool to use for assessing hip ROM in healthy children ages 5-10. The EasyAngle® demonstrated good to excellent intrarater and interrater reliability when used to measure five motions of the hip joint in this population. The findings of this study suggest that clinicians can reliably use this novel digital goniometer to measure hip ROM in pediatric clinical settings, or in preparticipation examinations for children who will be participating in youth sports. This study also established preliminary normative values by year of age using the EasyAngle® for measures of hip flexion, extension, abduction, internal rotation, and external rotation in a healthy population of children aged 5-10 that can be used in clinical practice to assess for impairments in body structure or function.

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# SUPPLEMENTARY MATERIALS

## Appendix 1

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