The Correlation between Reimers' Hip Migration Percentage and Stiffness of Hip Muscles measured by Shear Wave Elastography in Children with Cerebral Palsy

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Authors: H. Aslan, P. D. Analan; Adana/TR
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Purpose

Hip dislocation in children with cerebral palsy (CP) is a common and severe problem. It results in significant morbidity in terms of pain, postural difficulty, ambulation, disability and lower-extremity fractures. Abnormal muscle forces and muscle imbalance around the hip are believed to be the underlying cause of hip displacement by shifting the mechanical axis of the hip (1). Particularly hyperactivity of the hip flexors and adductors are reported as the contributing factors (2).

In 1980, Reimers defined the migration percentage (MP) to document the extent of hip subluxation lateral to the acetabulum. Measuring the percentage of hip migration with an anteroposterior radiograph is the best way to determine the degree of subluxation or dislocation of the hip joint (3). It is still used as the key tool to monitor, make decisions of preventive interventions or surgery and determine the progression of subluxation (4-7).

Reimers’ hip migration percentage (MP) is commonly used to examine the amount of lateral displacement of the femoral head in children with CP (3). An MP < 33% is considered as normal. In children with an MP between 33% and 40%, treatment based on other clinical signs including the follow-up progression of the MP over time is recommended (4, 6). Progression of the MP greater than 7% per year is considered to be worrying (4). Hips with an MP of #40% indicate the need for surgical intervention.

Shear Wave Elastography (SWE) is an Ultrasound (US) based technique which provides a quantitative measurement of the tissue stiffness by producing "push pulses" which result in shear wave propagation in the tissue.

Migration percentage is the percentage of the femoral head that sits outside the lateral margin of the acetabulum. In this study we aimed to assess the correlation between the MP and the stiffness of the hip muscles by SWE. Our second aim was to assess the correlations between the stiffness of hip flexor-extensor and abductor-adductor muscles.
Methods and Materials

Subjects

The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki and the study was approved by the local Ethics Committee and Institutional Review Board. Written informed consent was obtained from each child's parent.

This prospective study included 50 hips of 25 children with spastic CP. Inclusion criteria were as follows; having diagnosis of CP verified by a physiatrist who had an experience in in pediatric rehabilitation medicine, having at least MAS 1 spasticity in the flexor and adductor hip muscles aged from 2 to 10 years, having anteroposterior X-Ray of the pelvis within 2 months before enrollment.

Exclusion criteria were as follows; botulinum toxin or neurolytic agents (such as phenol or alcohol) injection within 6 months, previous surgery or any interventional procedures of trauma to the hips or lower limbs, having any other musculoskeletal or neurologic disorder except CP that affect lower limbs and hip.

The migration percentage (MP) measurement

The hips were examined with anteroposterior radiographs. Radiographs were taken with the patient in the supine position, the pelvis symmetric with respect to rotation, and the femurs in the neutral abduction/adduction position relative to the pelvis.

The migration percentage (MP) was measured on all radiographs. Radiographs were examined by both of the radiologists. The hospital's computer software for storing patient radiographic records was used to measure and calculate different angles and distances to minimize measurement errors. To evaluate the MP, the Hilgenreiner line (H) was ascertained by drawing a line between the Y-cartilages of both sides using the software’s angle measurement tool. Next, a second line, known as the Perkins' line (P), perpendicular to the first one, was drawn through the upper outer side of the acetabulum. Then, the innermost and outermost borders of the femoral head were defined, and two lines were drawn from those inner and outer lines intercepting at an angle of 90° to the H line. Finally, the migration percentage was calculated as the part of the femoral head outside Perkins' line divided by the total width of the femoral head multiplied by 100 (Fig.1).

US and Shear Wave Elastography (SWE) examinations
The stiffness of the gluteus medius and maximus, adductor magnus and iliopsoas muscles was measured by SWE. The US elastography evaluations were performed using a US ARFI elastography system (Acuson S 2000, Siemens Medical Solutions, Mountain View, CA, USA) with a linear transducer that enables scanning with a frequency ranging of 9-14 MHz. All of the B-mode US images and SWE images were performed by the same radiologist. All children were scanned on an examination bed in the prone position and then in the supine position. If voluntary contractions of the lower limb muscles occurred, the elastography examination has stopped. A virtual touch tissue quantification (VTQ) application was used for the quantitative assessment of tissue stiffness. All muscles were evaluated in longitudinal plane. For Shear Wave Velocity (SWV) measurements, a region of interest (ROI) cursor was placed at the mid-point of the muscles' largest circumference (Figs. 2 and 3). By VTQ a fixed ROI of 5x5 mm was used. SWV of each lesion were measured 3 times within the lesion. The mean values of these were used for analysis. SWV values are displayed as m/s (meters per second). For SWV, the range was 0-9 m/s. If the system displayed the SWV as non-numeric symbols (X.XX), and the measurements were repeated until valid values were found.

The radiologist was blind to the patients' clinical data.

The correlation between the Reimer's MP and the stiffness of hip flexors and adductors were analyzed. The stiffness of the gluteus medius and maximus, adductor magnus and iliopsoas muscles was measured. The stiffness of the hip flexor (iliopsoas) and extensor (gluteus maximus) muscles and hip adductor and abductor muscles were compared. Also the correlations among these muscle groups were assessed.

**Statistical Analysis**

Descriptive statistics were expressed as mean ± standard deviation. Kolmogorov-Smirnov test was used to test normality of data. The correlation of sonoelastographic findings with MP was assessed using Pearson correlation coefficient test. The correlation coefficients were interpreted as either excellent r≥0.91; good 0.90>r>0.71; fair 0.70>r>0.51; weak 0.50>r>0.31; or little or none r<0.3. The significance level was determined at p<.05. All statistical tests were performed using IBM SPSS Statistics software program (Chicago, IL, USA) for Mac version 20.0.
**Fig. 1:** The migration percentage (MP) measurement

**Fig. 2:** The measurement of muscle stiffness at iliopsoas muscle by SWE

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**Fig. 3:** The measurement of muscle stiffness at gluteus maximus muscle by SWE

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Results

The mean age of the study populations was 4.07± 2.25 years (range; 2-8 years). 13 of the patients were female and 12 of the patients were male.

There is a moderate positive correlation between MP and the stiffness of hip flexor muscles (r=0.70, p< .05). There is a moderate positive correlation between MP and the stiffness of hip adductor muscles (r=0.71, p< .05). The correlation between the stiffness of flexor and extensors is weak (r=0.10, p# .05). There is a weak correlation between the stiffness of abductor and adductor muscles (r=0.32, p# .05).
Conclusion

In this study we aimed to assess the correlation between the MP and the stiffness of the hip muscles. We showed a moderate positive correlation between MP and the stiffness of hip flexor muscles. Until recently, the correlation between the MP and the stiffness of the hip muscles in children with spastic CP had not been studied, to our knowledge.

A baseline radiographic view of the pelvis was recommended at 12-18 months, and follow-up of these patients at 6-month intervals has been suggested (8). If hip migration continues to worsen, injections of botulinum toxin and surgery may be needed. The dislocation can be avoided, by screening and preventive treatment of children with hips at risk (9). Hip dislocation in CP is preventable, by repeat radiographic and clinical examinations, and preventive treatment in hips (4,8,10). Elastography might be a complementary tool to assess the risk of hip displacement.

Spastic cerebral palsy causes excessive muscle tightness, called spasticity. This commonly affects the muscles in the back of the calf. Previously Kwon et al. showed the increased medial gastrocnemius muscle stiffness among children with CP when compared with the control group (11). Following-up the hip muscles stiffness may be a good predictive tool to evaluate the risk of hip dislocation. Further studies measuring muscle stiffness may be helpful.

The most important limitation of the study was that double blinding of the children and examiner was not practicable due to the nature of spasticity and the elastography technique.

In conclusion, we suggest that increased flexor and adductor muscle stiffness would be a potential high risk factor of hip dislocation in children with CP. Combinations of these imaging modalities (X-Ray and SWE) in the follow-up might provide a more accurate assessment of the hip dislocation risk among patients with CP.
References


