Effects of infant crawling experience on range of motion

Ali Cimbiz, PhD, PT, *Vahdettin Bayazit,* PhD.

ABSTRACT

Objective: The purpose of this study was to show the effects of infant crawling experience on shoulder and hip range of motion and trunk flexibility.

Methods: One hundred and twenty children who had attended the Child and Mothers Health Center in Kutahya City of Turkey between 2002 and 2003 were evaluated, and 40 children walking without assistance with normal motor development were divided into 2 groups, crawler group (CG) (N:20) and noncrawler group (NCG) (N:20). The CG children were selected to match with age of the NCG. Shoulder and hip range of motion and trunk flexibility were measured for assessment.

Results: No statistical differences were observed in all physical characteristics and range of movement (ROM) for girls and boys of each group ($p>0.05$). The CG girls were statistically found heavier and taller than NCG ($p<0.05$). The CG were found to start to walk later ($p<0.05$) and used walker devices less often ($p<0.01$) than the NCG. All hip ROM values were found statistically higher in NCG than CG ($p<0.05$, $p<0.01$) except hip flexion ($p>0.05$) and no statistical differences were found between groups shoulder ROM values ($p>0.05$), except NCG left flexion ($p<0.05$). The highest hip abduction ROM was measured in NCG boys and highest external rotation was measured in NCG girls. No statistical differences were found in trunk flexion and sit and reach test in both groups.

Conclusions: Crawling is an important developmental exercise for infants to gain joint stabilization especially on the hip joint, and parents should facilitate their infant's to crawl and maintain suitable environmental conditions.

Neurosciences 2005; Vol. 10 (1): 34-40

A newborn infant has crawling instinct right from birth, however, mobility is delayed until the bones, joints and ligaments are strong enough to support and actively propel the infant into all corners of their newly found world. Babies will usually be ready to crawl actively at about 9-10 months.[1-7] Once infants start to crawl, they can thoroughly investigate their previously inaccessible world: exploring every available inch of floor space, and on their journey testing every found morsel in their path to see whether it is food. Crawling is merely an indication that to walk the infant needs more time to achieve the necessary coordination and a required level of physical development. Movement skills may be gained by categorizing them with developmental hierarchy. At the bottom of the hierarchy are reflexes, which dominate the motor behavior of infants for the first 3 or 4 months after birth. The early locomotor milestones, including rolling over, creeping, crawling, standing, walking with support, and walking independently are at the next level up the hierarchy. At the top level of the hierarchy are specialized movement skills sometimes referred to as ontogenetic

From the Physical Therapy and Rehabilitation Department (Cimbiz), Health Institution of Higher School and Department of Biology (Bayazit), Faculty of Sciences and Arts, Dumlupinar University, Kutahya, *Turkey*.

Received 7th March 2004. Accepted for publication in final form 5th June 2004.

Address correspondence and reprint request to: Dr. Ali Cimbiz, Assistant Professor, Physical Therapy and Rehabilitation Department, Health Institution of Higher School, Dumlupinar University, 43100 Kutahya, *Turkey*. Tel. +90 535 393 8164. E-mail: alicimbiz@mail.dumlupinar.edu.tr

(development of an individual) skills because they are not demonstrated by all persons, but are specific to the needs and interests of a particular person.[1-3]

Children who did not crawl before they started to walk are those in which no locomotor strategy was observed prior to independent walking. Bottos et al[4] and Robson et al[5] defined these as children who, from the sitting position, stood up and walked. Others define them as children who passed from the rolling phase or from the sitting position to the upright position with support presenting reptilian movements such as with atypical pattern, sliding on the buttocks, and dragging or rolling on the abdomen. These children started walking with support first and then without.[6] For this reason, and perhaps with a desire to see their child reach the walking milestone, parents are placing their infants in childhood walking equipment. In fact, studies indicate that infants who use these devices may actually develop locomotor problems due to the establishment of a faulty walking pattern.[7] No more studied were found about infants who did not crawl before walking. The purpose of this study was to show effects of crawling on shoulder and hip range of motion in infants.

Methods. Inclusion criteria was full-term babies with a known gestational age of 37-42 weeks, male or female, 18-36 months age and walking without assistance. All children had normal motor development, healthy infants and no neurological or orthopedic disorder history. One hundred and twenty accompanied infants who had attended the Village Clinic for Child and Mothers Health in Kutahya city of Turkey between 2002-2003 were evaluated and 40 children walking without assistance and had normal motor development were divided in 2 groups, the crawler group (CG) (N:20) and noncrawler group (NCG) (N:20). The CG children were selected to age match with the NCG children. The parents were initially informed of the objective of the work and of the subsequent accompaniment; the children were only included in the study after obtaining the consent of the parents. After the child had been waiting in the pediatrics room with the minimum amount of external interference possible, the evaluations were conducted by the examiner in a medical consulting-type room in the village clinic. The evaluations were only made when the child presented in good clinical condition and proved cooperative during the exam. Because of unfamiliarity with the examiner, parents helped to maintain correct position when measuring the passive range of motions.

Crawling histories were taken by interviewing mothers, and the infant's files of the Child and Mother's Health Center. At interview, the mothers also were asked about using the walker or other tools, living environments and motor behaviors. Children who did not crawl before they started to walk are those in which no locomotor strategy was observed prior to independent walking. In this study we defined these as children who, from the sitting position, stood up and walked.

The shoulder and hip were chosen for measurement because of their large size, easiness for measurement of range of movement (ROM) and importance in normal motor development. All infants wore non restricting clothing while having their shoulder and hip joints measured. None of the children complained of forced pain with movement. All measurements were performed 3 times and the best one was recorded. A plastic, 41 cm universal goniometer was use to measure the movements of flexion, extension, abduction, internal and external rotation. Children were positioned as for visual estimation tests. The child moved the affected extremity (thumb pointing upwards) actively and than examiner assisted him/her to the end of range of motion. The same examiner made all goniometric measurements. The shoulder flexion angle was formed by aligning the goniometer with the lateral epicondyle of the humerus, the middle of the glenoid fossa, and a vertical line in the coronal plane. The abduction angle was formed by aligning the goniometer with the lateral epicondyle of the humerus, the middle of the posterior glenohumeral joint line, and a vertical line in the sagittal plane. The internal and external rotation angle was formed by aligning the goniometer with the ulna styloid process, the olecranon process of the ulna, and a horizontal line in the transverse plane.[8] To measure the amount of hip flexion and hyperextension, the goniometer pin was placed on the greater trochanter of the femur and the goniometer was aligned vertically along the shaft of the tibia. Measurement was made with the child lying supine and flexing the hip by raising one leg in the air. The child was placed in the prone position to measure the amount of hip hyperextension. For the angle of hip rotation, the knee was flexed to 90°, and the leg was moved internally and externally in the sitting position.[9]

Trunk flexion and lateral flexion were measured using a tape, and sit and reach tests were used for assessment of trunk movements. Distance between end of middle finger and the floor was used for measurement of trunk flexion, right and left lateral flexion between standing and flexion position. The sit and reach test is the most common of all the flexibility tests. It measures the flexibility of the lower back and hamstrings and a box 30 cm (12 inches) high and a meter rule was used. The child tried to reach a distance while sitting at a sit-and-reach box.[10,11]

The SPSS Windows 9.0 statistical program was used for all statistical analyses. Results were presented as mean ± SD. Statistical evaluation of the data was performed by one way ANOVA to find groups differences and the non-parametric Mann-Whitney U test was used for comparing groups (NCG and CG girls versus boys, NCG versus CG). Findings with an error probability value of less than 0.05 were considered statistically significant.[12]

Results. No statistical differences were observed in all physical characteristics and ROMs for girls and boys of each group ($p>0.05$). The CG girls were found to be statistically heavier and taller than NCG girls and boys ($p<0.05$). In contrast, the CG boy's height and weight were observed similar with NCG girls and boys. The CG boys and girls started to walk later ($p<0.05$) and use the walker less ($p<0.01$) than NCG girls and boys. Age was observed to be similar in all groups (**Table 1**). Parents had a normal social economical statue in Turkey and only 40% of mothers in the NCG and 30% in the CG were working. Most parents in both groups (NCG 85%, and CG 75%) were living in apartment rooms restricted by household goods.

There were no statistical differences in all shoulder ROM between groups ($p>0.05$), except left shoulder flexion ($p<0.05$). The greater passive ROM (PROM) of left shoulder flexion was measured in NCG girls. The NCG girl's PROM for the left shoulder was statistically higher than NCG boys and CG girls ($p<0.05$). The NCG and CG girls left shoulder ROM was found similar (**Table 2**). All hip ROM values were found statistically significant in both groups, except hip flexion. The NCG girls and boys right and left hip extension ROM was measured higher than CG girls and boys ($p<0.01$). However, no statistical differences were found within boys and girls of each group ($p>0.05$). The highest hip abduction ROM was measured in NCG boys and was statistically more significant than CG girls and boys (left hip $p<0.01$, right hip $p<0.01$) but similar with NCG girls. Hip external rotation ROM was measured higher than internal rotation and highest ROM were found in right hip of the NCG girls. The NCG boy's right and left hip external rotation ROM were measured higher than CG girls ($p<0.05$) and similar with CG boys. The NCG girls and boys (only left internal rotation) hip internal rotation ROM were measured higher than CG girls and boys ($p<0.05$). Other ROMs were found similar (**Table 3**).

No statistical differences were found in trunk flexion and sit and reach test in both groups ($p>0.05$). The NCG girls and boys trunk right and left lateral flexion was measured higher than the CG girls and boys. Trunk movements within boys and girls of both groups were found similar (**Table 4**).

Discussion. Robson et al[5] determined that the majority (82%) of normal infants crawl on hands and knees as the predominant means of moving from place to place before they get themselves to standing. Others shuffle in a sitting position (9%), creep on the abdomen (1%) or roll (1%), and tend to walk much later than the crawlers. The earliest walkers have no observable prewalking locomotion, they just stand up and walk (7%). In many instances, the age at which one locomotor milestone is attained correlates well with the age at which subsequent milestones appear, thus permitting prediction of the age of standing and walking. In contrast to this study,[5] our infants were of the same age and the CG were found start to walk later and used less walker devices than the NCG.

Range of motion is related to joint stability, often determined by the laxity of the surrounding ligaments and muscles. One of the instruments to measure ROM is the goniometer.[2,3,7] The shoulder is shown to be more flexible by a significant amount in almost every measurement due to its shallow socket and fewer ligaments, however, the hip has a deep socket with strong surrounding ligaments and muscles. In this study no differences were found between all the physical characteristics within the boys and girls of each group. On the other hand, the CG girls were found heavier and taller than the NCG, and the CG boys and girls were found to start walking later than the NCG. Although weight and height are directly related to nutrition, they are also related to physical development faults, such as, walking without crawling.

In the Turkish population, the standard weight-height index is determined for a 2-3 year old girl as weight 12.2-14.2 kg and height 84-92 cm, and for boys, weight 12.7-14.7, and height 85-93 cm.[13] The NCG were found thinner and shorter than the CG and the standard Turkish population. In our study, parents had normal social economical statue and both groups were living in small apartment rooms restricted by household goods. The NCG used walkers for a longer time than the CG, but this difference does not have a strong effect on the locomotor system. Although, children in similar living conditions who did not crawl, had poor locomotor developments. In addition to these results, we did not find the reasons why those children did not crawl.

Estimated annual sales of walkers are more than 3 million. Older studies have found that 55-92% of infants between 5 and 15 months of age use walkers. Parents give various reasons for using walkers, to keep the infant quiet and happy, to encourage mobility and promote walking, to provide exercise, and to hold the infant during feeding. One third of parents in one study used walkers because they believed that walkers would keep their infants safe.[14-22] Ridenour et al[23] investigated the influence of pre-walking practice in an infant walker on the onset time of independent walking in 15 pairs of

Table 1 - Demographic data of the children.

Features	Noncrawler group (NCG) N = 20		Crawler group (CG) N = 20		
Groups*	Girls	Boys	Girls	Boys	***p*****
Number	10	10	10	10	
Start to crawl (months)	-	-	7.8±1.4 (5-10)	7.7±1.2 (6-10)	NS
Start to walk (months)	11 ± 1.1 (9-13)	11 ± 1.7 (9-15)	12.6 ± 1.5 (11-15)	12.7 ± 1.4 (11-15)	<0.05
Age (months)	25 ± 7.1 (18-36)	27.7 ± 7.4 (18-36)	31.2 ± 6.7 (18-36)	28.9 ± 8.2 (18-36)	NS
Height (cm)	83.8 ± 9.9	83.6 ± 7.3	94.6 ± 9.4	90.9 ± 13.8	<0.01
Weight (kg)	11 ± 1.7	11.2 ± 2.6	13.4 ± 1.5	12.6 ± 2	<0.01
Using walker or other tools (months)	12 ± 1.3	12 ± 1.5	10 ± 1.6	9 ± 1.8	<0.01

*No statistical differences within groups (male versus female) (Mann Whitney U test). NS - not significant
**to compare the group differences between the NCG and CG groups, data listed as mean ± SD, (Mann Whitney U test).

Table 2 - Range of motion (ROM) of the shoulder.

Shoulder motion	Noncrawler group (NCG) N = 20		Crawler group (CG) N = 20		
Groups*	Female	Male	Female	Male	***p*****
Right shoulder (degree)					
Flexion	197.5 ± 10.6	188 ± 5.9	189.5 ± 11.7	190.5 ± 10.9	NS
Hyperextension	90.3 ± 13	88.5 ± 17.3	80.5 ± 24.2	87 ± 16.5	NS
Abduction	180 ± 0	180 ± 0	180 ± 0	180 ± 0	NS
Internal rotation	93 ± 8.9	99.5 ± 8	101 ± 14.3	101.5 ± 17.8	NS
External rotation	122 ± 12.7	116.5 ± 16.3	123.5 ± 23	116.5 ± 16.5	NS
Left shoulder (degree)					
Flexion	197 ± 8.6†	187.5 ± 5.4	189 ± 10.8	187.5 ± 8.3	<0.05
Hyperextension	91.3 ± 14.4	90 ± 16.3	78 ± 20.4	89 ± 17.1	NS
Abduction	180 ± 0	180 ± 0	180 ± 0	180 ± 0	NS
Internal rotation	93 ± 8.9	97 ± 11.1	98.5 ± 12.9	98.5 ± 13.6	NS
External rotation	120.5 ± 11.4	116 ± 14.3	119 ± 20.4	114 ± 13.9	NS

*No statistical difference within groups except left shoulder flexion (NCG girls versus boys)
**to compare the group differences between the NCG and CG groups, data listed as mean ± SD. NS - not significant
†NCG girls shoulder passive range of motion statistically higher than NCG and CG boys, $p<0.05$ (Mann Whitney U test)

Table 3 - Range of motion (ROM) of the hip.

Hip motion	Noncrawler group (NCG) N = 20		Crawler group (CG) N = 20		
Groups*	Female	Male	Female	Male	***p*********
Right hip (degree)					
Flexion	138.5 ± 2.4	131.5 ± 8.8	135 ± 8.8	132 ± 7.2	NS
Hyperextension	54.5 ± 9.9	56.5 ± 10.8	39.5 ± 6.9	44.5 ± 9.9	<0.01
Abduction	81 ± 11	86.7 ± 20.9††	70 ± 12.5	64 ± 9.1	<0.01
Internal rotation	63 ± 8.2	65 ± 6.2	60.5 ± 16.7	51.5 ± 9.4	<0.05
External rotation	79 ± 11.7	71.5 ± 9.1	56.6 ± 10.3	68 ± 16.2	<0.05
Left hip (degree)					
Flexion	139 ± 2.1	132 ± 8.9	134 ± 6.4	131 ± 8.1	NS
Hyperextension†	54 ± 8.8	58 ± 9.5	39.5 ± 6.9	44.3 ± 10	<0.01
Abduction	80 ± 9.4	87.2 ± 21.2††	72 ± 12.3	64.5 ± 8.6	<0.01
Internal rotation‡	65 ± 12.3	64 ± 5.7	54 ± 11	54.5 ± 12.1	<0.05
External rotation‡‡	75.5 ± 11.4	71.5 ± 9.7	58 ± 12.1	70 ± 15.1	<0.05

*No statistical difference within groups (NCG and CG boys versus girls), data listed as mean ± SD. NS - not significant (Man Whitney U test)
**to compare the group differences between the NCG and CG groups.
†NCG hip extension higher than CG (p<0.01)
††NCG boys hip abduction higher than CG girls and boys (p<0.01)
‡NCG hip internal rotation higher than CG girls and boys except left hip (p<0.05)
‡‡NCG hip external rotation higher than CG girls (p<0.05)

Table 4 - Trunk flexibility.

Trunk motion	Noncrawler group (NCG) N = 20		Crawler group (CG) N = 20		
Groups*	Female	Male	Female	Male	***p*********
Trunk mobility (cm)					
Flexion	35.8 ± 4.1	34 ± 6.1	32.6 ± 9.6	35 ± 7.2	NS
Right lateral flexion†	20.7 ± 3.1	20.4 ± 2.6	17.3 ± 4.4	16.8 ± 4.1	<0.05
Left lateral flexion†	21.2 ± 2.8	20.4 ± 2.8	16.1 ± 5.5	16.4 ± 4	<0.05
Sit and reach	24.7 ± 4.1	23.3 ± 3.2	22.8 ± 3.6	23.6 ± 4.2	NS

*No statistical difference within groups (NCG and CG boys versus girls), data listed as mean ± SD. NS - not significant (Man Whitney U test)
**to compare the group differences between the NCG and CG groups.
†NCG trunk lateral flexion higher than CG (p<0.05)

twins and found that use of the infant walker did not influence the onset of independent walking.

Studies have also show that the crawling experience is important to the development of sensory and motor systems of the body.[1,24,25] Liao et al[24] investigated the association between pre-walking locomotor strategies and psychomotor developments in 50 children with mental retardation. Children in the crawling group had more advanced developments than those in the shuffling group, and they reported that crawling may not be a necessary prerequisite for early ambulation or better cognitive function in mental retardation children.[24] Robson et al[5] studied normal children with various patterns of crawling and related these factors with the age these children started to walk. He distinguished 2 groups: the group that walked earlier formed by children who did not crawl and those with the crossed pattern (children with typical crawling pattern) besides those who started walking later, formed by children with the atypical pattern, and concluded that these different crawling patterns are more closely related to a variation of normal patterns than with a pathological condition. Crawling activities in prone helps infants with upper and lower extremity strength, hand development, muscular elongation and equilibrium reactions needed for future rolling, crawling, pulling to stand, and walking. Failure to crawl inhibits a child's ability to explore his environment. Not crawling also developed weakness in muscles and ligaments weak from disuse, the stability of the joint is reduced thus affecting their ability to function adequately. Joint stability is inversely proportionally correlated with joint ROM. When increasing stability joint ROM is decreased, and decreasing stability increases joint ROM.[10,11] In addition, bone mass density increased with developing motor activity in the upper and lower extremities.

Studies on cerebral palsy showed diminished activities of the lower limbs and pelvis, which are associated with fractures.[26] Because our subjects are children, all shoulder and hip ROMs were found higher than standard adult values. Shoulder ROM degrees were similar in both groups, except for left shoulder flexion. In contrast, all hip ROM degrees were found significant in both groups, except for hip flexion. Studies determined that the shoulder ROM for flexion is 170-180°, hyperextension 50-80°, abduction 170-180°, internal and external rotation 70-80° degrees by universal goniometer. For the hip ROM, flexion of 100-125°, hyperextension 10-30°, abduction 40-45°, internal and external rotation 40-45° was determined.[10,11] The ROM degrees were higher than these standard results. Shoulder ROM results can be expectable because the shoulder joint is lax and its stability is provided by surrounding muscles. In contrast, hip joint ROMs were found more lax in the NCG than the CG. These results have shown that non crawling activities particularly affected the hip joint.

In infant hip extension, limitation decreased from 10° at 9 months to 3° at 24 months. At 9 months, external rotation was greater than internal rotation in all cases, and no differences were found between girls and boys.[25,27] In this study we did not find any limitation in hip extension because of age and active assistive goniometric measurements. In addition, trunk mobility especially lateral flexion was more mobilized in the NCG. Trunk and hip joint hypermobility can cause gait faults, columna vertebralis disorders and many problems for the musculoskeletal system in future development. The patients with low back pain, but without evidence of sacroiliac joint dysfunction had significantly greater external hip rotation than internal rotation bilaterally, whereas those with evidence of sacroiliac joint dysfunction had significantly more external hip rotation than internal rotation unilaterally, specifically on the side of the posterior innominate.[9,28] Thus, further studies are need to evaluate the effects of crawling on the musculoskeletal system and motor development.

Consequently, crawling is an important developmental exercise for infants to gain joint stabilization especially on the hip joint, and parents should facilitate their infant's to crawl and maintain suitable environmental conditions.

References

1. McEwan MH, Dihoff RE, Brosvic GM. Early infant crawling experience is reflected in later motor skill development. ***Percept Mot Skills*** 1991; 72: 75-79.
2. Block SD. Me and I'm Great: Physical Education for Children. 2nd ed. Minneapolis: Burgess Publishers; 1977.
3. Magill RA, Ash MJ, Smoll FL. Children in Sport. 2nd ed. Chicago: Human Kinetics Publishers; 1982. p. 134-156
4. Bottos M, Dalla Barba B, Stefani D, Pettena G, Tonin C, D'Este A. Locomotor strategies preceding independent walking: prospective study of neurological and language development in 424 cases. ***Dev Med Child Neurol*** 1989; 31: 25-34.
5. Robson P. Prewalking locomotor movements and their use in predicting standing and walking. ***Child Care Health Dev*** 1984; 10: 317-330.
6. Largo RH, Molinari L, Weber M, Comenale-Pinto L, Duc G. Early development of locomotion: significance of prematurity, cerebral palsy and sex. ***Dev Med Child Neurol*** 1985; 27: 183-191.
7. Crouchman M. The effects of babywalkers on early locomotor development. ***Dev Med Child Neurol*** 1986; 28: 757-761.
8. Hayes K, Walton JR, Szomor ZL, Murrell GA. Reliability of five methods for assessing shoulder range of motion. ***Aust J Physiother*** 2001; 47: 289-294.
9. Cibulka MT, Sinacore DR, Cromer GS, Delitto A. Unilateral hip rotation range of motion asymmetry in patients with sacroiliac joint regional pain. ***Spine*** 1998; 23: 1009-1015.
10. Luttgens K, Hamilton N. Kinesiology: Scientific Basis of Human Motion. 9th ed. Madison: Brown & Benchmark; 1997.

11. Cole TM, Tobis JS. Measurement of musculoskeletal function: Goniometry. In: Kotte FJ, Lehman JF, editors. Krusen's Handbook of Physical Medicine and Rehabilitation. 4th ed. Philadelphia: W. B. Saunders; 1990. p. 20-32.
12. Coakes SJ, Steed LG. SPSS Analysis Without Anguish: Version 7.0, 7.5, 9.0 for Windows. 2nd ed. Brisbane: John Wiley and Sons; 1999.
13. Abaoglu C, Aleksanyan V. Teshisten Tedaviye: Appendix. 7th ed. Istanbul: Filiz Kitapevi; 1975. p. 1163-1175.
14. Yan JH, Thomas JR, Downing JH. Locomotion improves children's spatial search: a meta-analytic review. ***Percept Mot Skills*** 1998; 87: 67-82.
15. American Academy of Pediatrics. Committee on Injury and Poison Prevention. Injuries associated with infant walkers. ***Pediatrics*** 2001; 108: 790-792.
16. Mayr J, Gaisl M, Purtscher K, Noeres H, Schimpl G, Fasching G. Baby walkers -- an underestimated hazard for our children. ***Eur J Pediatr*** 1994; 153: 531-534.
17. Kavanagh CA, Banco L. The infant walker: a previously unrecognized health hazard. ***Am J Dis Child*** 1982; 136: 205-206.
18. Stoffman JM, Bass MJ, Fox AM. Head injuries related to the use of baby walkers. ***Can Med Assoc J*** 1984; 131: 573-575.
19. Rieder M, Schwartz C, Newman J. Patterns of walker use and walker injury. ***Pediatrics*** 1986; 78: 488-493.
20. Trinkoff A, Parks PL. Prevention strategies for infant walker-related injuries. ***Public Health Rep*** 1993; 108: 784-788.
21. Chiaviello CT, Christoph RA, Bond GR. Infant walker-related injuries: a prospective study of severity and incidence. ***Pediatrics*** 1994; 93: 974-976.
22. Kauffman IB, Ridenour M. Influence of an infant walker on onset and quality of walking pattern of locomotion. ***Percept Mot Skills*** 1977; 45: 323-329.
23. Ridenour MV. Infant walkers: developmental tool or inherent danger. ***Percept Mot Skills*** 1982; 55: 1201-1202.
24. Liao HF, Lee SC, Lien IN, Chen CJ, Soong WT, Tseng CC. Locomotor strategies before independent walking: prospective study of 50 mentally retarded children. ***J Formos Med Assoc*** 1992; 9: 334-341.
25. Phelps E, Smith LJ, Hallum A. Normal ranges of hip motion of infants between nine and 24 months of age. ***Dev Med Child Neurol*** 1985; 27: 785-792.
26. Shiragaki J, Iwasaki N, Nakayama J, Fujita K, Ohto T, Matsui A. Regional variation in bone mineral density and motor function in children with cerebral palsy (Abstract). ***No To Hattatsu*** 2001; 33: 37-43. Japanese.
27. Forero N, Okamura LA, Larson MA. Normal ranges of hip motion in neonates. ***J Pediatr Orthop*** 1989; 9: 391-395.
28. Ellison JB, Rose SJ, Sahrmann SA. Patterns of hip rotation range of motion: a comparison between healthy subjects and patients with low back pain. ***Phys Ther*** 1990; 70: 537-541.