Effect of Weight-Bearing in Abduction and Extension on Hip Stability in Children With Cerebral Palsy

Caroline Martinsson, PT, MSc; Kate Himmelmann, MD, PhD

Habiliteringen Björkängen (Ms Martinsson), Borås, Sweden; and The Queen Silvia Children's Hospital (Dr Himmelmann), Göteborg, Sweden.

Purpose: To study the effect of 1 year of daily, straddled weight-bearing on hip migration percentage (MP) and muscle length in children with cerebral palsy who were nonambulatory. **Methods:** Participants stood upright in maximum tolerated hip abduction and hip and knee extension ½ to 1½ hours per day for 1 year. Controls, matched for age, motor ability, and surgery, were derived from a national cerebral palsy follow-up program. **Results:** Participants using straddled weight-bearing after surgery had the largest decrease in MP (n = 3, 20 controls; $P = .026$). Children using straddled weight-bearing at least 1 hour per day for prevention also improved (n = 8, 63 controls; $P = .029$). Hip and knee contractures were found only in controls. **Conclusion:** Straddled weight-bearing, 1 hour per day, may reduce the MP after adductor-iliopsoas-tenotomies or prevent an MP increase and preserve muscle length in children with cerebral palsy who did not need surgery. Larger studies are needed to confirm the results. **(Pediatr Phys Ther 2011;23:150–157)**
Key words: cerebral palsy, cerebral palsy/physiopathology, cerebral palsy/rehabilitation, child, exercise therapy/methods, hip dislocation/prevention & control, patient positioning, posture/physiology, tenotomise, treatment outcome, weight bearing

INTRODUCTION AND PURPOSE

Cerebral palsy (CP) includes a group of disorders of development of movement and posture, causing activity limitation attributed to nonprogressive disturbances that occurred in the developing fetal or infant brain.[1] The motor ability of children with CP can be classified into 5 levels using the Gross Motor Functional Classification System (GMFCS).[2] Children at levels I and II can walk without support, children in GMFCS III are expected to learn to walk with a mobility device, whereas children in GMFCS IV-V cannot sit or walk without support.

Children with CP often have increased muscle tone, weakness, and muscle imbalance.[3] Therefore, they are at greater risk for developing muscle contractures and hip dislocation. This may result in significant morbidity in terms of pain; contractures; sitting, standing, and walking problems; fractures; pelvic obliquity; and scoliosis.[4] To prevent hip dislocation and severe contractures, a CP follow-up program (CPUP) was established in southern Sweden in 1994.[5] In 2005, CPUP was appointed as a National Health Care Quality Register, encompassing all children with CP in Sweden, born in 2000 and later. Participation starts when a diagnosis of CP is considered.

The program includes a standardized follow-up of each child's gross motor function (GMFCS),[2] passive range of motion (ROM),[6] and a standardized radiological follow-up of the hips, since ROM alone does not predict hip displacement.[7-9] Intervals between radiological

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Correspondence: Caroline Martinsson, PT, MSc, Habiliteringen Björkängen, S-501 82 Borås, Sweden (caroline.martinsson@vgregion.se).
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follow-ups are based on the child's GMFCS level, as children in GMFCS III-V are those with increased risk for hip dislocation.[10] This information is a prerequisite for early intervention to prevent hip dislocation.[4]

A frequent problem in children with severe CP is the combination of coxa valga (neck-shaft angle of the femur higher than normal) and high adductor and iliopsoas tone, which forces the femoral head against the lateral rim of the acetabulum causing inhibition of growth.[7,11] This can be viewed on a radiograph as an imprint of the femoral head on the lateral rim, similar to a gothic arch.[12] The migration percentage (MP) of the hip is the percentage of the femoral head lateral to the border of the acetabulum.[8] The MP is calculated using an anteroposterior pelvic radiograph.[12] Children who are developing typically have a 0% or negative hip MP. Teenagers seldom have MPs more than 5%.[8] As early as 18 months of age, children with CP at GMFCS levels III to V have significantly higher MPs than children developing typically, with a yearly deterioration of a mean MP of 7%.[8] Reports reveal continuing hip dislocation in 60% of these children.[8,10,13]

Several studies report improvements in hip integrity by using 12 to 24 hours of postural management intervention to prevent leg scissoring.[14,15] Bilateral adductor-iliopsoas-tenotomies (AITs) are recommended when the MP exceeds 40%.[8] To improve the effect of surgery, bilateral long-leg casts in maximal abduction are sometimes used postoperatively.

Weight-bearing is the term used for daily, controlled, supported standing for children who cannot stand on their own.[16] A stander is a tool to help children practice weight-bearing. Initiation of daily weight-bearing is recommended at 12 to 18 months of age.[17] Children need to stand fairly upright in order to load their body weight onto their feet.[18] The time spent in standing varies considerably. The extent to which parents and physiotherapists agree on the importance of standing and the value parents place on this therapeutic goal for their child will determine how often parents will place their child in standing. However, evidence for the efficacy of weight-bearing is limited. Stuberg[17] recommends weight-bearing at least 4 to 5 hours per week to prevent osteoporosis. Weight-bearing also facilitates the development of stable hips.[4,17,19] Several kinds of standers exist. In the Gazelle stander, hip and knee extension and the degree of abduction (0°-35°) can be varied individually for each leg. This can be easily done with the child standing (Figure 1).

The idea for this research project emerged from a single-subject pilot study. A 3-year-old boy diagnosed with spastic CP, GMFCS level V, stood in 30° of hip abduction, 2 hours daily for 3 years following AIT surgery. At the end of 1 year, MP decreased from 50% to 16%. This change occurred more rapidly and was greater than expected by the surgeon and, despite severely increased muscle tone, remained for almost 3 years after surgery (until the child's death). In addition, passive ROM was preserved: hip abduction greater than 30°, hip extension at 0°, and knee extension greater than −10°. This may theoretically be explained by the straddled position, where maximum tolerated, daily abduction and extension of the hip and knee were used, centering the femoral head in the acetabulum during weight-bearing, allowing uninhibited growth of the acetabular rim.[12] Simultaneous, sustained stretching of the adductor and iliopsoas muscles was achieved for an extended period, in a position preventing any forceful contraction of the adductor muscles. Compliance was increased by the ease with which the stander could be adjusted for comfort during stretching/standing sessions.

Fig. 1. Child straddled weight-bearing in a Gazelle stander.

Aims

This case series aimed to study the effect of straddled weight-bearing 1 to 1.5 hours per day on hip MP and muscle length for 1 year in children with CP who were nonambulatory either (1) following bilateral AITs or (2) as a preventive measure for children who had not had AIT surgery.

METHODS

Participants

Inclusion criteria for this study were a considered or confirmed diagnosis of CP, GMFCS levels III to V, and 2 to 6 years of age. Children at GMFCS level III who could already walk with a handheld device were excluded.

Data for the total population (N = 205) fulfilling the inclusion criteria were collected from the National

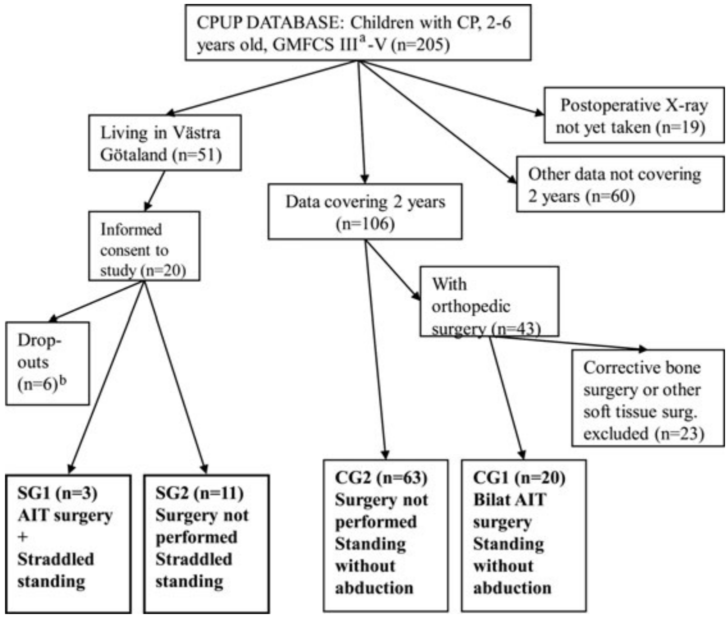

Fig. 2. Inclusion criteria and selection of participants. Abbreviations: CPUP, cerebral palsy follow-up program; CG1, control group 1; CG2, control group 2; SG1, study group 1; and SG2, study group 2. [a]Only children without independent walking with aids were included. [b]Six participants left the study. This was due to increased muscle tone in 2, preferred body support walker as standing device in 2, erroneous CP diagnosis in 1, and baseline x-ray missing in 1 child.

Quality Register CPUP (Figure 2). The children identified from the database included in the study met the following criteria: availability of 2 consecutive years of data for children without surgery and availability of pre- and postoperative radiographs for children having had surgery. On the basis of these criteria, 79 children were excluded. Children having had soft tissue surgery other than AIT surgery or corrective bone surgery ($n = 23$) were also excluded.

Informed consent was obtained from the parents of 20 of the 51 eligible children in the Västra Götaland region. During the course of the study, 2 children dropped out because of increased muscle tone and general health problems, 2 because they preferred a body support walker as a standing device, 1 because of an erroneous CP diagnosis, and 1 because of lack of a baseline x-ray (see Figure 2 legend). The remaining children were divided into study group 1 (SG1) ($n = 3$) with participants after bilateral AIT surgery and study group 2 (SG2) consisting of participants without AIT surgery ($n = 11$). Ten of these children accomplished weight-bearing 1 to 1½ hours daily during the study year; the other 4 children stood only 30 minutes daily. The age of the children at study entry was from 2 years, 2 months to 6 years.

The remaining 83 children, matched for age and GMFCS levels, were divided into control group 1 (CG1) ($n = 20$), children who had had bilateral AIT surgery, and control group 2 (CG2) ($n = 63$) for whom surgery had not been considered. The distribution of GMFCS levels and CP types in the 4 groups are shown in Table 1.

Ethical approval was obtained from the regional ethics committee in Lund exclusively for studies of data from the National Quality Register CPUP, and from Göteborg for the straddled weight-bearing intervention.

Intervention and Procedure

Children in SG1 required surgery, which was performed within 1 month prior to entering the study. Children in SG2 entered without requiring surgery. Each child stood in the Gazelle stander (R82, Gedved, Denmark) with maximum tolerated hip abduction and hip and knee extension. All children stood upright at 0° to 10° of forward tilt. The goal was 1½ hours of standing per day, in 1 to 3 daily sessions. At the delivery of the stander, the first author instructed parents and other caregivers on how to handle the Gazelle stander. Side supports with trunk straps maintained trunk symmetry. Often, an additional side support helped the pelvis remain centered (Figure 1). Each family had at least 3 visits and 3 additional telephone contacts during the intervention year. Adjustments were made at every visit.

Parents recorded time spent in the stander and degrees of hip abduction in a logbook. They were also asked to comment on factors influencing straddled weight-bearing. No restrictions were placed on the other interventions received by the children in the study. General interventions may have been daily manual stretching, training to maintain antigravity postures, using special chairs and wheelchairs to achieve some variation for the child, weight-bearing with feet close together, and using orthoses.

Outcome Measures

The primary outcome measure was MP and ROM for hip abduction and hip and knee extension. A manual for acquiring standardized measurements was available at the CPUP Web site.[4] For MP, the accuracy is within the range of ±8% for radiographs taken on different occasions.[12]

TABLE 1.
Epidemiological Data, Distribution of GMFCS Level, Cerebral Palsy Type, and Time in Stander by Group

	Children Male/ Female, n	Mean Age and Range at Study Start, y	GMFCS Level III/IV/V	Spastic, n	Dyskinetic, n	Mixed, n	Time in Stander (h/d) ½ / 1 / 1½
Study group 1	1/2	4.1 (2.7-5.5)	0/1/2	0	3	0	1 / 0 / 2
Control group 1	10/10	3.5 (1.8-6.1)	0/6/14	7	12	1	. . .
Study group 2	4/7	3.6 (2.1-6.0)	1/5/5	4	7	0	3 / 3 / 5
Control group 2	34/29	3.6 (1.3-5.7)	6/34/23	40	20	3	. . .

Abbreviation: GMFCS, Gross Motor Functional Classification System.

Migration percentage was calculated from radiographs by the local orthopedic surgeon and entered in the CPUP database. For measurements of ROM, interrater reliability is lower than intrarater reliability but acceptable for ROM (hip abduction and hip and knee extension) used in this study.[6] The child's physiotherapist assessed ROM by goniometer on each occasion and entered it in the CPUP database.[6]

Assessment

Data from the start and end of the baseline year and after the intervention year were collected from the CPUP database. Only the hip with the highest MP at the end of the baseline year (ie, the worst) was included in calculations.[13] The effect on MP was visualized in a coordinate system with the same units on both axes, according to Reimers.[8] The coordinate area displayed 2 regions, the upper including all hips with an increase in MP and the lower including hips with a reduction in MP.[8] To allow for uncertainty in the measurements of MP, the diagonal was replaced by 2 lines encompassing ±10% of the actual value obtained.

Statistical Analyses

Because the groups were small and normal distribution was not expected, nonparametric tests were chosen. Linear multiple regression analysis was used to determine correlations between 1 hour or more spent daily in the stander, AIT surgery, and combined procedures. To determine differences between groups, the Mann-Whitney *U* test was performed in SPSS, version 15.0.

In the present study, the CPUP guidelines were applied to ascertain limits of passive ROM (when a contracture was present for children who were nonambulatory) and limits for an unstable hip, defined as hip abduction of 30°, hip extension of 0° and knee extension of −10°, and MP greater than 33%.[4,14] The number of children exceeding these limits before and after intervention was also used to compare data.

RESULTS

The range of time spent in the straddled weight-bearing position was ½ to 1½ hours per day (Table 1). Linear regression analysis of the entire group revealed that the correlation between children in the straddled weight-bearing position 1 or more hours per day and change of MP was significant ($P = .000$) (n = 11/86 controls). The mean decrease of MP was 8.6%. The correlation between AIT surgery and decrease of MP was also significant, with a mean decrease of 11.9% ($P = .000$) (n = 23/74). The combination of AIT surgery and the study intervention in the 3 subjects in SG1 resulted in a significant decrease with a mean of 20.8% ($P = .035$).

The individual development of MP for participants in SG1 is shown in Figure 3. The MP for each child in SG1 was less than 33% at the end of the study (n = 3). Nine of 20 children in CG1 still had an MP of 33% or more, 7 of which had an MP of 40% or more 1 year after surgery (Table 2). For 1 child in SG1, as well as for the pilot case, a 2-year follow-up was performed, showing sustained improvement after continued straddled weight-bearing (Figure 3). The change in MP during the intervention year in SG1 is shown in Figure 4, along with the results of their controls (CG1).

Among children who used straddled weight-bearing as prevention (SG2), a significant reduction of MP was found for those weight-bearing 1 hour or more daily when correlated for GMFCS levels ($P = .029$) (n = 8/63). Three children in SG2 completed the year weight-bearing only 0.5 hours per day (Figure 5). Their MP increased by 0%, 9%, and 11%. The change in MP during the intervention year in SG2 is shown in Figure 5, along with the results for the control group (CG2). The changes in median MP for all groups are shown in Figure 6.

There were no statistical differences for hip and knee extension between SG1 and CG1 or between any ROM measure in SG2 and CG2. Hip abduction improved significantly by a mean of 15° in SG1 compared with CG1 ($P = .002$) (n = 3/12; see Table 2).

Hip abduction was less than 30° for 1 of 3 children in both CG1 and SG1 before surgery. The 3 children in SG1 had hip abduction of at least 30°, hip extension of 0°, and knee extension of −10° at the end of the study (Table 2). In contrast, 2 children with dyskinetic CP GMFCS V in CG1 had a hip extension contracture of 10° 1 year postoperatively. No major improvements were seen in either hip abduction or knee extension within the CG1 group.

One child used an asymmetric degree of abduction (20/25°), because further abduction caused an oblique pelvis, which negatively affected the spine.

After the study, no one in SG2 had restricted hip extension, compared to 7 of 63 children (11%) in CG2.

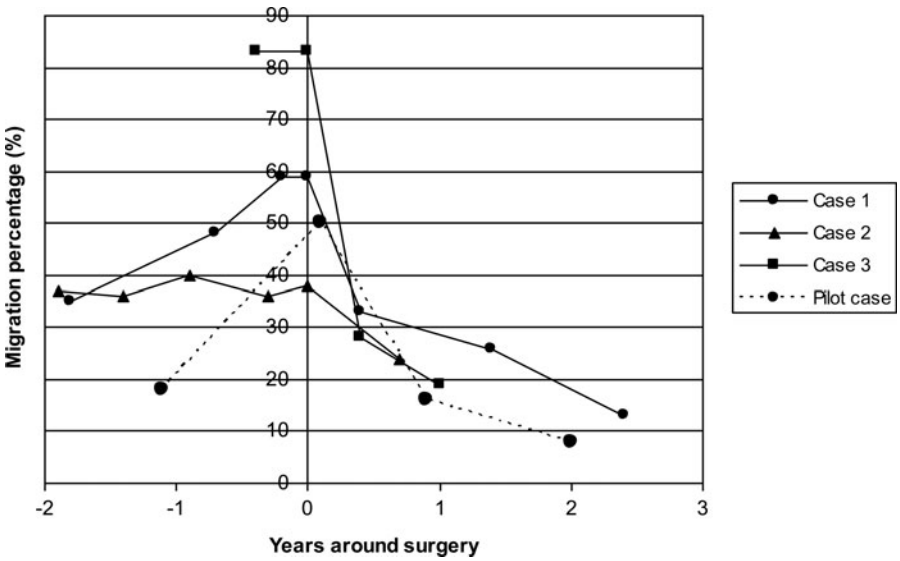

Fig. 3. Study group 1: migration percentage of worst hip pre- and post-adductor-iliopsoas-tenotomy surgery. Pilot case is included in the diagram.

TABLE 2

Distribution of Children With Severe Contracture or Restricted Range of Motion According to Limits in Cerebral Palsy Follow-up Program Related to Groups

	Migration Percentage		Hip Abduction		Hip Extension		Knee Extension	
	Severe Value MP≥ 40%	Observation Value 40%>MP≥33%	Contracture ≤20°	Restricted ROM 21°-29°	Contracture ≤−10°	Restricted ROM −9 to −1°	Contracture ≤20°	Restricted ROM −19 to −11°
Study group 1 (n = 3)								
End baseline	2	1	1	1	0	0	1	1
End study	0	0	0	0	0	0	0	0
Control group 1 (n = 20) (ROM n = 12)[a]								
End baseline	11	6	1	3	0	1	0	1
End study	7	2	2	0	2	1	1	0
Study group 2 (n = 11)								
End baseline	1	0	2	0	0	0	0	0
End study	1	1	0	1	0	0	0	1
Control group 2 (n = 63)								
End baseline	3	3	3	4	3	1	0	2
End study	1	6	1	2	3	4	0	0

Abbreviation: ROM, range of motion.
[a]Range-of-motion data present from 12 of the 20 children.

DISCUSSION

Children with CP and severe motor impairment are at risk for hip dislocation. This may lead to a series of secondary complications, such as pain, scoliosis, and impaired sitting. The expected outcome for children with CP who are nonambulatory is deterioration in MP by 7% yearly.[8] In this study, calculations were based upon data from the worst hip, according to the work of Terjesen.[13] He argued that because the degree of dislocation in the worst hip is of most importance to the child, it seems adequate to include only 1 hip for each patient in the statistics. If both hips were included, the real progression in MP could have been underestimated.

In Figure 6, the significant changes in MP were seen as increasing values that were interrupted by surgery in SG1 and CG1, with a greater change in SG1. Also, the break in SG2 is visible. The linear regression analysis of the change in MP showed that the effect of straddled weight-bearing for 1 hour or more daily for 1 year is comparable with the effect of surgery. However, this result is enhanced by the children in SG1 who had the combination of interventions, as these seem to reinforce one another. As yet, only 4 children (the pilot case and the 3 children in SG1) have tested the combined interventions and all showed a significant effect. The results from this case study and a pilot study warrant further investigation with a larger group of children.

The 3 children in SG2 performing weight-bearing only ½ hour daily showed results in accordance with the expected outcome of deterioration in MP of 7% yearly.[8]

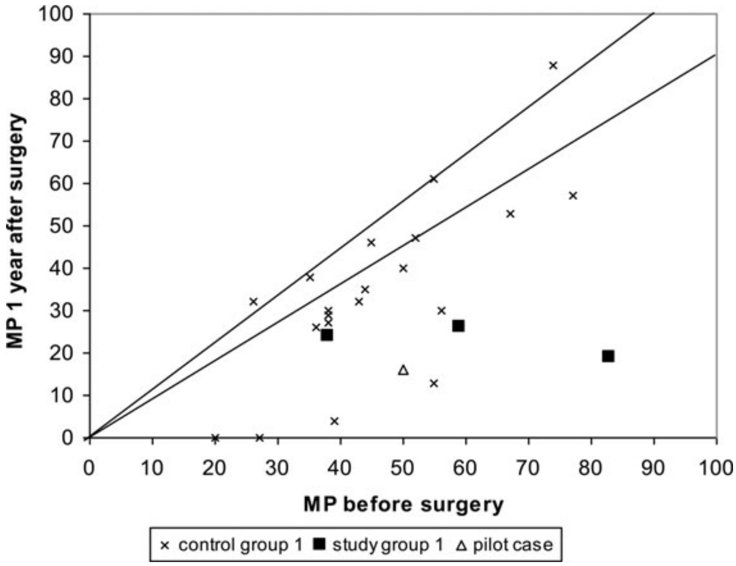

Fig. 4. Migration percentage (MP) for study group 1 and control group 1: pre- and postoperative to adductor-iliopsoas-tenotomy surgery, worst hip. According to Reimers, the coordinate area is divided into two regions: the upper including all hips with increase in MP and the lower including all hips with a reduction in MP.[8] To make allowance for uncertainty in the measurements of MP, the diagonal was replaced by 2 lines embracing ±10% of the actual value obtained.

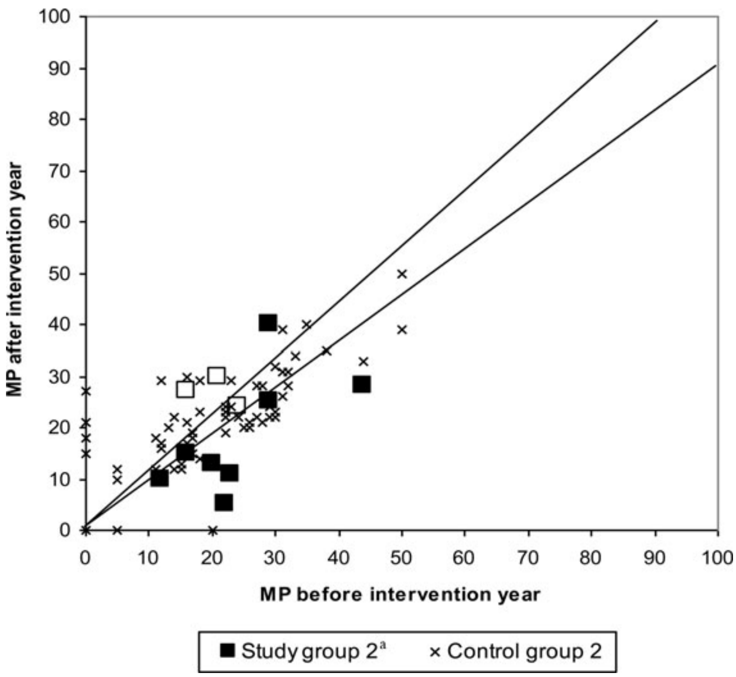

Fig. 5. Migration percentage (MP) for study group 2 and control group 2 second year, worst hip. [a] Filled symbols = standing ≥1 hour/day, unfilled symbols = standing ½ hour/day.

Thirty minutes of daily weight-bearing therefore seems insufficient to achieve an effect in terms of reduction of MP without surgery. In combination with surgery, 30 minutes seems sufficient to have an effect. However, the children standing 1½ hours daily had a much greater effect.

Results may be due to the contribution of stretching muscles to avoid acetabular rim compression by the femoral head. Moreover, the position itself may affect the central part of the acetabulum, thereby facilitating formation of a well-rounded acetabulum, matching the shape of the femoral head.

Adequate ROM is a goal in itself.[4] However, ROM does not predict hip displacement.[7–9] Nonetheless, ROM was recorded in this study because weight-bearing in a Gazelle stander provides sustained stretching of the hip adductors, and hip and knee flexors, which has a more positive effect than daily manual stretching.[20] The definition of sustained stretching varied in a recent review by Pin.[20] The 8 to

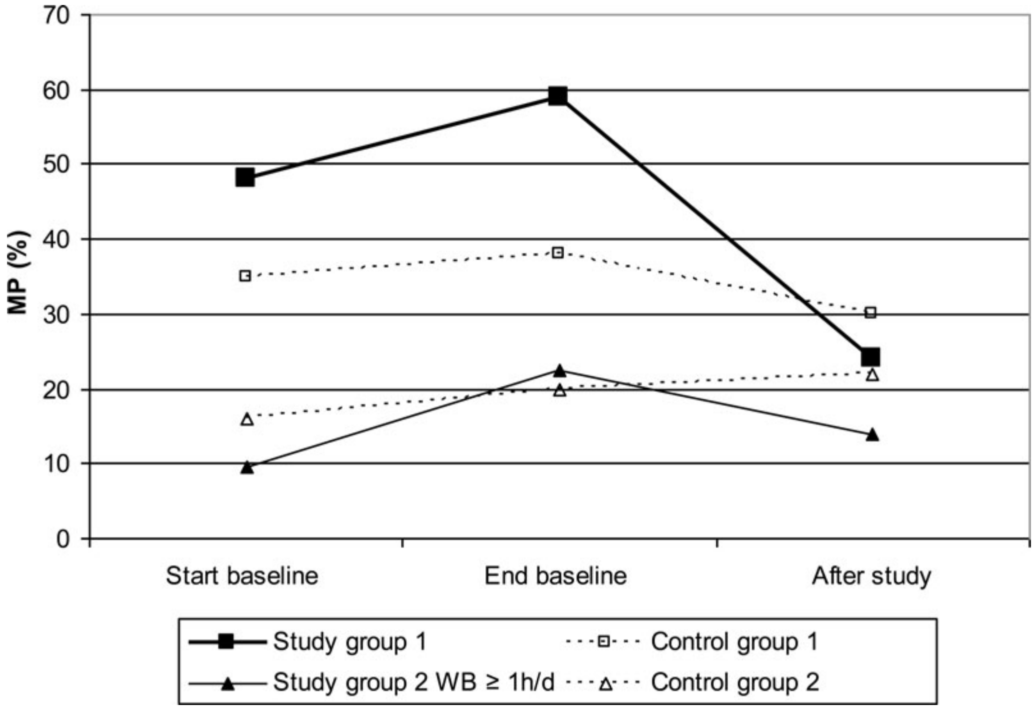

Fig. 6. Change of median worst hip over time for all groups.

10 hours per week of hip adductor and flexor stretching in the present study surpassed all stretching time in that review. After every standing session, parents reported a considerable time for adductor and flexor activity to reach the same high level as prior to the standing procedure. For example, taking steps while held by parents was easier after the standing session because the feet did not cross the midline.

For most children with severe CP, weight-bearing is part of their daily treatment.[16,17,19] In Sweden, the aid of choice for weight-bearing is generally a standing shell placed in a wheel-equipped device.[4] The inner width of the foot bar determines width of the feet when standing. In a standing shell in the neutral position, the spastic adductor muscles may serve as a lever and increase displacement.[14] Perhaps children who use their spasticity for weight-bearing and steps also should use straddled weight-bearing. These children might benefit from having some period of time during the day when there is less pressure on the acetabular rim, possibly allowing it to grow more typically, as abnormal stress would be reduced.

The fact that most children with CP who are nonambulatory develop coxa valga may be a sufficient argument for placing them in abduction while in a stander.[13–15] However, the present study does not answer the question of whether 30° of abduction is necessary to keep the acetabular rim free from pressure. In the present study, all children except 1 managed to use the 30° of abduction achievable in the stander. Hip extension to 0° was also achieved in this position.

Two articles reported 25% to 100% of total body weight loaded on the feet while in standers, and that weight-bearing was strongly correlated to the angle to load line.[17,18] If standing upright had less tilt than 20° to the vertical, foot loading was not substantially reduced. Therefore, in the present study, great effort was applied to the procedure of placing the child in the stander. All children stood upright with 0° to 10° of forward tilt from the vertical, which facilitated head control and maximized weight-bearing on the feet.

In the logbooks, parents recorded factors that they thought facilitated or obstructed straddled weight-bearing. Facilitated head control was one such factor. The most frequently noted positive factor was that daily manual stretching was reported to be easier to carry out. Four children had injections of botulinum toxin in their hip adductors during the intervention year. The result in terms of increased ROM was not statistically detectable, but those families reported greater ease in carrying out the weight-bearing procedure and a prolonged period, when daily manual stretching was easier to perform than stretching after injections prior to the intervention year. Another facilitator was the ease with which standing posture could be adjusted for abduction and extension while the child was standing. The table attached to the stander allowed the child to play while standing. Four children with dyskinetic CP were able to perform fine motor activities more effectively while standing than sitting in their special chairs, for example, using contacts or pointing at pictures. Therefore, they used a Gazelle stander both at home and at nursery school. These viewpoints from the children and their families are important when choosing interventions.[21]

Treatment and management of the child with CP is time-consuming.[22] A great risk exists for taking too much time for treatment at the expense of free playtime. The combined procedure of sustained stretch, weight-bearing, and prevention of hip displacement occurring simultaneously, while the child is playing or attending class, is a matter to consider when choosing the child's posture in weight-bearing. This view was also highlighted by several parents.

The strength of this study was the yearlong length of testing the intervention and the broad clinical applicability. All the children in the study groups kept their stander for continued straddled weight-bearing after the study year. One weakness was the small number of participants. Moreover, children capable of movement in a body-supporting walker do not always accept standing still. The children who terminated participation for this reason had fairly stable hips. The motivation for the parents to continue might have been limited. Another limiting factor was the parents' capability to create and maintain daily routines.

CONCLUSION

The children weight-bearing with maximal achievable abduction and 0° of hip extension for at least 1 hour per day achieved reduction of MP and preserved their ROM, compared with the controls. This may enhance the result of AIT. Straddled weight-bearing without having surgery first strongly correlates to reduction of MP. However, as the number of children was small, further studies are needed to confirm the results.

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