The Effect of Gross Motor Therapy and Orthotic Intervention in Children With Hypotonia and Flexible Flatfeet

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ABSTRACT

The purpose of this study was to determine the effect of gross motor (GM) therapy alone versus GM therapy plus soft insert orthoses on gait parameters and the medial longitudinal arch (MLA) in children with hypotonia and flatfeet. Twenty-five children aged 18 months to 5 years who demonstrated developmental delays and hypotonia with flatfoot dysfunction participated in this study. Two intervention groups (GM therapy alone and GM therapy plus foot orthoses) were studied over a period of 6 months. The arch index was used to assess the MLA pre- and postintervention. Gait parameters (velocity, stride length, stance time, and cadence) were assessed using the GAITRite™ system. There was a significantly greater improvement in pre- versus postintervention ($p<0.003$) in the arch index for the orthosis-added group compared with the GM therapy-only group. There was no difference between groups in the mean change in velocity, stance time, stride length, and cadence; however, both groups approached age-appropriate norms. Although GM therapy alone may have improved some gait parameters toward age-appropriate norms in young children with hypotonia and flatfeet, the addition of orthoses also significantly modified the arch index, possibly preventing long-term complications. (*J Prosthet Orthot.* 2011;23:149–154.)

KEY INDEXING TERMS: children, flatfoot, orthosis, orthotic, hypotonia

The typically developing infant has flexible flatfeet which develop a normal arch during the first 10 years of life. Flexible flatfeet are those in which the longitudinal arch is present when the foot is unloaded but absent when loaded. A pathological flatfoot has an absent arch when both loaded and unloaded.[1]

The prevalence of flexible flatfeet in typically developing 3-year-old children is purported to be 54% (<1% were pathological) with a higher incidence in males and children who are obese.[2] These numbers decline with age. El et al.[3] found that by 9 years, only 17.2% had moderate or severe flexible flatfeet using Staheli's index.[4]

Risk factors for presence of pediatric flatfoot include ligamentous laxity, obesity, equines, and tarsal coalitions among others.[1,5] Symptoms may include fatigue and pain. Ligamentous laxity may also be associated with a delay in walking due to joint instability.[1]

According to Gould et al.,[6] treatment for flatfeet in the normally developing population should not be done to affect development of the arch because it occurs naturally. Wenger et al.[7] showed that flexible flatfeet in young children with typical development slowly improve with growth and that

intensive treatment with corrective shoes or inserts for a 3-year period did not alter the natural history of arch development. Instead, treatment in the normally developing population is for relief of pain and prevention of future disability.[8,9] Pronated feet have been associated with development of heel spurs, hallux valgus, hammertoes, knee pain, hip and knee degenerative disease,[10,11] low back pain,[12,13] plantar fasciitis,[14] and ankle sprains.[15]

In children with atypical development, however, if ligamentous laxity is part of a developmental syndrome, the presence of flatfeet is unlikely to decrease with maturity.[1] Such laxity is a known component of disorders such as Down syndrome, Prader-Willi syndrome, and other diagnoses associated with hypotonia.[16] Although clinical judgment suggests the need for joint protection and stabilization in such cases, there is minimal evidence for the effectiveness of orthotic intervention, nor have the criteria for treating flatfoot dysfunction in such children been scientifically established.

Cappello and Song[8] report that stability for ambulation and transitional activities may be improved with orthoses in the neuromuscular foot on a case-by-case basis. This was shown by George and Elchert[17] who found improved scores on the Peabody Developmental Motor Scale II in one child with hydrocephalus and hypotonia who was fitted with custom-modified stabilizing foot splints. Orner et al.[18] reported improved balance skills after application of a foot orthosis in a 5.5-year-old boy with a learning disability and excessive pronation. The use of a foot orthosis combined with ongoing early intervention physical therapy resulted in a 12-month gain in 5 months (Peabody Developmental Gross Motor Scales) in a child with gross motor (GM) delay, hypotonia, and flexible flatfeet.[19] There was also the visual appearance of a medial longitudinal arch (MLA). Pitetti and Wondra[20] found that application of a minimum controlled dynamic foot or-

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thosis in children with GM developmental delay improved Peabody scores within 7 days, and changes were still apparent after 2 months of wear.

In larger studies, Martin[21] showed that a flexible supra-malleolar orthosis significantly improved scores on the GM Function Measure standing and walking, running, and jumping dimensions in a population of 14 children with Down syndrome. According to Selby-Silverstein et al.,[22] Subort-holene™ foot orthoses used in children with Down syndrome immediately decreased heel eversion and decreased the variability of stance-phase walking speed, the pronation-supination index, foot length contact, and transverse plane foot angle. The effectiveness of orthotic intervention on the dimensions of the MLA and further parameters of gait, however, has not been reported in this population.

Measurement of the MLA has been done in various ways. Use of electronic footprints, a capacitive pressure distribution platform,[23] or a laser surface scanner,[2] although effective, are not accessible for the typical clinician. The simple measurement of footfalls on paper, however, provides a clinically accessible means.

Kanatli et al.[24] found a positive correlation between the arch index from footfalls on paper and radiographic analysis of the lateral talo-horizontal and lateral talo-first metatarsal angles. They conclude that use of footprint data is effective for individual office examinations.

In a comparison of various footprint measurements (footprint index, Staheli index, Chippaux-Smirak index, arch index, truncated arch index, and arch length index) Queen et al.[25] concluded that footprint indices were highly correlated with navicular height (measured using a mirrored foot photograph box) and that both were valid measures of MLA height. Of the footprint measurements, the footprint index was most reliable followed by the Staheli index.

In an effort to contribute to evidence-based practice, this study was undertaken to more objectively determine if a soft orthosis, in addition to standard GM therapy, would make a significant difference in the dimensions of the MLA and dimensions of gait. It was hypothesized that a significant difference would be apparent after a 6-month period of intervention.

METHODS

PARTICIPANTS

Twenty-five children with hypotonia and flatfoot dysfunction aged 18 months to 5 years participated in this study. This age group was chosen in the interest of protecting joints from secondary complications as the arch is forming, and to provide increased stability during refinement of gait. All subjects were already receiving GM therapy twice a week for motor delay accompanied by low muscle tone, lower limb weakness, gait deficits, and balance impairments. Each was ambulating independently without the use of an assistive device; none had previously worn orthoses. Although medical diagnoses

varied, each child was identified by the child's physical therapist as hypotonic with flexible flatfeet. This finding was confirmed by the primary investigator by a decreased tonal response to passive movement[26] and the visual absence of a MLA in bilateral stance, which was present with Jack-toe-rise.[8]

Children were randomly divided into GM therapy plus orthosis versus GM therapy-only groups. Each member of the orthotic group was fitted for orthoses by the primary investigator. Thirteen children were randomly assigned to the GM plus orthotic group and 12 to the GM therapy-only group. Further group demographics may be viewed in Table 1.

INSTRUMENTATION

Arch Index

The arch index, developed by Staheli,[4] is a measure of the MLA. The arch index is considered reliable for measuring changes in the MLA when clinicians do not have radiographic images.[4,24,27] Using a dusted footprint in resting standing position, the width of the arch and the heel were measured, and the arch index (arch width/heel width) was determined.

Gait Parameters

The GAITRite™ system (Gold Model), a portable gait analysis tool, was used to measure gait parameters.[28] It consists of computer hardware, software, and a 12-feet carpet lined with sensors. The sensors capture footfall impressions that are used by the computer to calculate spatial and temporal gait parameters. This system has been shown to have strong validity and reliability in assessment of gait.[29-32] The Gold model was selected for this study because of increased sensor sensitivity to capture pediatric data.

Table 1. Gender, age, and diagnosis by group

	GM therapy + orthoses	GM therapy only
Age (mean ± SD)*	2.92 ± 0.86	2.75 ± 0.87
Gender	8 males/5 females	10 males/2 females
Medical diagnosis		
Down syndrome	5	4
Prader Willi	0	1
Congential hereditary	1	0
Muscular dystrophy		
Macrocephaly	1	0
Tuberous sclerosis	1	0
Autism	1	1
ADHD		1
Developmental delay	4	5

*At least 18 months.
GM, gross motor; ADHD, Attention Deficit Hyperactivity Disorder.

Figure 1. Cascade Hotdog© Orthosis.

Orthoses

A soft insert orthosis (Figure 1) with medial arch support and calcaneal heel correction to vertical via medial heel posting was used. The soft orthosis was selected over a hard orthosis to increase wearing comfort and adherence.

Data Analysis

Descriptive statistics were computed on all variables using SPSS 17.0.[33] An independent samples t-test was used to compare group means of the difference pre- versus postintervention for each variable (the arch index, velocity, stride length, stance time, and cadence). The significance level for all comparisons was set at $p<0.05$.

PROCEDURES

This study was approved by the Institutional Review Board of Loma Linda University. After being informed of the purpose and procedures in this study, eight southern California pediatric outpatient clinics volunteered to participate and provided letters of agreement. Primary treatment physical therapists identified potential subjects with low muscle tone and flatfoot dysfunction, and the children were then screened by the primary investigator according to inclusion criteria (Table 2). The study was explained to parents of qualifying children who gave voluntary signed consent. Each child was randomly assigned to one of two groups—GM therapy plus orthoses or GM-therapy alone.

Children assigned to the orthotic group were measured for a pair of orthoses (donated to the families) by the primary investigator. Parents were instructed to have the child wear the orthoses in his or her shoes during everyday activities and to continue with GM therapy. Children assigned to the nonorthotic group continued GM therapy as before.

At the beginning of the study, gait parameters of velocity, stride length, stance time, and cadence were recorded using the 12-feet GAITRite carpet placed on a hard surface. Each child walked with shoes on for the length of the carpet three times, and data from the three trials were combined. After

Table 2. Inclusion criteria

Criteria	Operational definition
Hypotonia	Decreased tonal response to passive movement of ankle, knee, and elbow joints
Bilateral ROM	≥20 degrees ankle dorsiflexion with knee extended
	≥0 degrees knee extension
	≥0 degrees elbow extension
Receiving gross motor therapy for gait, balance, and gross motor impairments	Either physical therapy 2×/week or physical therapy 1×/week, and occupational therapy 1×/week
Flexible flatfeet	Visual absence of an arch in quiet bilateral stance but present with Jack-toe-rise[8]
No prior orthosis usage Independent in ambulation without the use of an assistive device	

ROM, range of motion.

gait assessment, the investigator dusted the child's bare feet with chalk and placed the child in standing position with feet on black paper to obtain bilateral foot impressions. These impressions were then used to determine the arch index. After 6 months of treatment, a repeat measurement of gait parameters and the arch index was performed. As at baseline, gait was performed with shoes on, and in the orthotic group, orthoses were included.

RESULTS

ARCH INDEX

There was a significantly greater improvement in the arch index from pre- to postintervention in the orthotic group compared with the control group ($p = 0.003$) (Figure 2). Only the orthotic group moved closer to the age-appropriate mean as listed by Staheli et al.[4] (Table 3).

GAIT PARAMETERS

Mean stride length, cadence, and velocity moved closer to age-appropriate levels in both the orthosis and GM therapy-only group after 6 months of intervention. The mean change in each of these variables was not significantly different between groups (Table 3). The percentage of time spent in stance was unchanged.

DISCUSSION

ARCH INDEX

In this study, children with hypotonia and flatfoot dysfunction who received specific orthotic intervention showed a significantly greater change in their arch development when compared with the GM therapy-only group. The resultant elevation in the MLA and subsequent foot supination suggests a change in the soft tissues of the foot over the 6 months of wearing the orthoses. Such a change was believed by Bordelon[34] to be the result of joints and ligaments assuming the correct position over time, which in turn enhances stability of the foot and improves muscle control during the gait cycle.[18] In this study, despite the change in the MLA, there was no clear evidence of the effect of orthoses on gait. However, according to Kogler, an adequate orthotic arch control mechanism decreases the strain on the plantar apo-

Figure 2. Change in arch index after treatment with and without orthoses.

neurosis.[14] The GM therapy-only group, which did not experience these changes, may potentially be at risk for later foot pain, injury, and lack of stability.

Staheli et al.[4] studied 441 normal subjects using footprint data and established the normal arch index values for children. Average age in this study's GM plus orthotic group was 2.9 years. The measured arch index (1.28 ± 0.14) was at the margin of Staheli's normal range for that age group (0.6–1.3 years, estimated from graph). This range was defined as two standard deviations from the mean.[4] Therefore, the mean arch index of children in this study was outside the range of 95% of children of their age. After orthotic intervention, the average index (1.11 ± 0.24) approached the age-expected mean of 0.9. This was not the case, however, in the GM-only treatment group where values remained unchanged (mean = 1.25 ± 0.08).

The enhanced arch development after orthosis wear in this study stands in contrast to the findings by Gould et al.[6] and Wenger et al.[7] that corrective shoes or inserts did not affect the ultimate development of the child's arch. Gould et al., however, studied normal children and also found that arch development occurred faster with the presence of an arch support in the first 2 years. The study by Wenger et al. specifically excluded any child with a neurologic condition or syndrome known to be associated with excessive laxity, the subjects in this study. Therefore, results from these studies cannot truly be compared. The only known study for comparison of changes in the MLA in the population with hypotonia is the case study by Buccieri.[19] The child in this study not only had improved GM function and balance but also demonstrated the appearance of a MLA after application of foot orthoses.
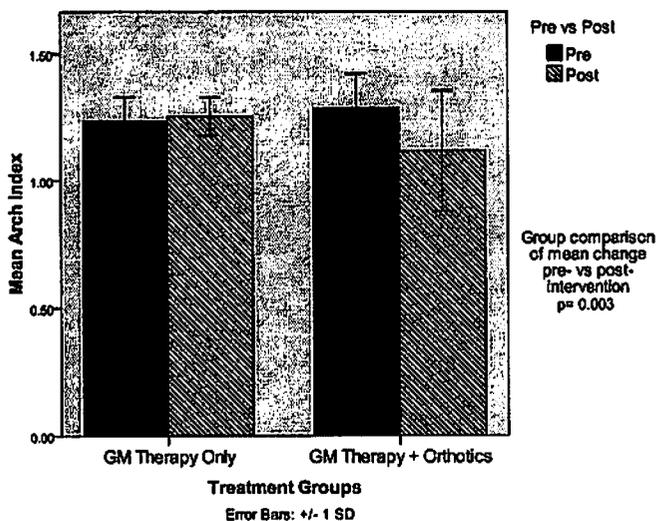
GAIT PARAMETERS

In the discussion of gait parameters, changes must be compared with age-appropriate norms. Campbell et al.[35] present norms (modified from Sutherland et al.[36]) for various

Table 3. Gait parameters and arch index by group

	GM therapy + orthosis (n = 13)		GM therapy only (n= 12)		Group comparison of mean change pre- vs. postintervention *p*	Published means for age 3 yr[37]
	Preintervention (mean + SD)	Postintervention (mean + SD)	Preintervention (mean + SD)	Postintervention (mean + SD)		
Velocity (cm/s)	88.25 + 22.90	93.38 + 13.78	72.47 + 17.84	90.88 + 11.77	0.113	86
Cadence (steps/min)	167.68 + 48.94	158.96 + 20.77	143.71 + 26.45	150.88 + 18.51	0.297	154
Stride length (cm)	65.06 + 16.85	71.56 + 14.20	61.04 + 13.96	72.96 + 10.76	0.149	67
Stance time (% of gait cycle)	65.13 + 10.52	63.62 + 7.67	66.46 + 9.26	65.61 + 6.79	0.932	60
Arch index	1.28 + 0.14	1.12 + 0.24	1.23 + 0.10	1.25 + 0.08	0.003	0.9 for age 3 yr (Staheli et al.[4])

GM, gross motor.

time and distance parameters of gait from 1 to 7 years. These are included for comparison in Table 3.

Because stride length and velocity improved in both groups, it suggests both a maturational effect due to increased limb length and also greater control as a result of GM therapy. The nonorthotic group showed the greatest improvement because they were further delayed at baseline compared with expected norms (Table 3).

Although the cadence of the orthotic group tended to slow, and the nonorthotic group tended to increase, both groups approached age-appropriate norms. Stance time remained unchanged in both groups because they were already near the expected stance time of 60% as the study began.[35]

This study did not find changes in average gait parameters due to wearing orthoses. Although not comparing means, Selby-Silverstein et al.[22] found an immediate decrease in the variability of gait parameters after application of novel foot orthoses in children with Down syndrome, perhaps due to increased stability. Subjects in the study by Wenger et al. had an average age of 61.3 months; in this study, average age was 34.0 months. Although by age 36 months the gait pattern is considered mature,[35] the age discrepancy in these studies make them difficult to compare.

LIMITATIONS

In the interest of joint protection and enhanced stability during developing gait, the average population in this study was under 3 years of age. According to Campbell, this age group may not be ideal for three-dimensional gait analysis because of their small physical size, their reluctance to cooperate, and their immature gait patterns.[34] The same reasoning applied to this study may have contributed to the large variability in gait parameters.

Because withholding GM intervention would be unethical in this population, there is no such control group for comparison. Therefore, although it appears that GM therapy resulted in some gait parameters being closer to age-expected norms, it is impossible to draw definitive conclusions.

Although this study's data show that the arch index is changed with orthosis wear, future studies should take a longer term look at the effect of such changes in the prevention of pain and dysfunction. Use of standardized developmental tests would help to relate such changes to function.

CONCLUSIONS

This study examined the effectiveness of GM therapy intervention and soft orthoses in children with hypotonia and flatfoot dysfunction. Results showed that although GM therapy appears helpful in changing some characteristics of gait toward age-appropriate norms, the addition of orthoses also modified the dimensions of the arch index. This change in the arch is believed to provide future joint protection and the prevention of damage. In summary, it appears that the development of the MLA is enhanced with orthosis wear in this

population and that the arch index is a clinically useful tool for assessment of these changes.

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