Treadmill Training of Infants With Down Syndrome: Evidence-Based Developmental Outcomes

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ABSTRACT. *Objective.* On average, infants with Down syndrome (DS) learn to walk about 1 year later than nondisabled (ND) infants. The purpose of this study was to determine if practice stepping on a motorized treadmill could help reduce the delay in walking onset normally experienced by these infants.

Methods. Thirty families of infants with DS were randomly assigned to the intervention or control group. All infants were karyotyped trisomy 21 and began participation in the study when they could sit alone for 30 seconds (*Bayley Scales of Infant Development, Second Edition* 1993, item 34). Infants received traditional physical therapy at least every other week. In addition, intervention infants received practice stepping on a small, motorized treadmill, 5 days per week, for 8 minutes a day, in their own homes. Parents were trained to support their infants on these specially engineered miniature treadmills. Every 2 weeks research staff went into the homes and tested infants' overall motor progress by administering the *Bayley Scales of Infant Development, Second Edition,*[1] monitored growth status via a battery of 11 anthropometric measures, and checked parents' compliance with physical therapy and treadmill intervention. The primary measures of the intervention's effectiveness were comparisons between the groups on the length of time elapsed between sitting for 30 seconds (entry into the study) and 1) raising self to stand; 2) walking with help; and 3) walking independently.

Results. The experimental group learned to walk with help and to walk independently significantly faster (73.8 days and 101 days, respectively) than the control group, both of which also produced large effect size statistics for the group differences. The groups were not statistically different for rate of learning to raise self to stand but there was a moderate effect size statistic suggesting that the groups were meaningfully different in favor of the experimental group.

Conclusions. These results provide evidence that, with training and support, parents can use these treadmills in their homes to help their infants with DS learn to walk earlier than they normally would. Current research is aimed at 1) improving the protocol to maximize outcome; 2) determining the impact of treadmill practice on walking gait patterns; 3) testing the application to other populations with a history of delays in walking; and 4) determining the long-term benefits that may accrue from this form of activity. *Pediatrics* 2001;108(5). URL: http:// www.pediatrics.org/cgi/content/full/108/5/e84; *motor development, Down syndrome, early intervention, walking.*

Infants with Down syndrome (DS) begin to walk, on average, about 1 year later than infants who are nondisabled (ND).[2,3] This is part of the sequence of delayed and diminished motor abilities this population faces; the gap between infants with and without DS grows wider with age. Walking is a particularly salient skill for young children because its impact is multidimensional, affecting cognitive, social, as well as subsequent motor development.

In his editorial in *Developmental Medicine and Child Neurology*, Bax[4] wrote that walking is "more than simply the ability to ambulate . . . it is the ability to stand upright in social situations . . . can be little doubt that it has an effect on body image . . . Standing upright places one on the same plane as the rest of the world, enabling one to be more aware of the importance of his body in relation to other people." When infants with DS begin to walk their opportunities to interact and play with their age-mates increases significantly. Motor activity-play provides exploration and opportunities for new forms of cognitive development to emerge.

Research involving normally developing infants has demonstrated that the ability to locomote increases children's understanding of depth, locations of objects and themselves in space, and of hidden objects.[5,6] Biringen and colleagues[7] documented, in particular, an increase in affective behavior (positive interactions as well as clashes of will) of both mother and infant with walking onset, particularly for infants who walk earlier, rather than later in age. In her work with preschool-aged children with mobility problems, Butler[8,9] observed an immediate impact when these children learned to use powered wheelchairs. They increased their language, play, and exploration dramatically. Most fascinating were their increased efforts to produce self-propelled locomotion. The rewarding experience of being able to control their own movement in one context motivated them to make further efforts to learn and be active when not in the wheelchair.

Parents of infants with DS identify walking as one of the goals they value most for their young children. Well-intentioned family members and friends repeatedly ask if their child has begun to walk and talk,

a disconcerting question as delays become longer. Sloper[10] studied factors that impacted on the stress levels and satisfaction with life of 123 families of children with DS. For mothers, the primary caregivers, stress levels were strongly related to their child's self-sufficiency. When children with disabilities can walk alone, handling and physically caring for them becomes easier for their parents.

Therapeutic intervention programs for infants with DS are based on the assumption that motor activity that is in excess of, or more appropriate than that which is experienced naturally in the home, will aid development. Theoretical arguments notwithstanding, a deeply held cultural notion exists that practice makes perfect. Published accounts of the impact of intervention programs on the motor domain lead to a mixed interpretation. Gibson and Harris[11] concluded that only 3 of 9 studies showed reliable training effects on the gross motor behavior of infants and young children. Yet Nilholm[12] reviewed the same set and concluded that the "bulk of evidence suggests positive effects for gross motor training." We agree with Nilholm's interpretation of this literature but believe it is important to point out that less benefits have been demonstrated in the locomotor status of young children with DS.[13–16] Based on his review of early intervention literature and DS, Nilholm recommends that more efforts should be devoted to studying various training methods. We believe that the impact of training is strengthened, and significant results obtained, when specific skills are targeted. Badke and DiFabio[17] argued that therapeutic intervention should focus on limb movement patterns "as they fit into a full functional pattern because individual muscle action may be insignificant to the biomechanics involved in a total integrated motor response." The question related to upright locomotion becomes, how does one target walking before an infant actually begins to stand and walk?

It has long been known that newborn infants demonstrate a stepping reflex when held upright so their feet touch a firm surface.[18,19] This pattern normally disappears about 4 to 6 weeks postnatally, at least under the traditional elicitation procedures. Some very exciting research, however, indicates that this innate capacity does not have to disappear and may, in fact provide a key to how we can help infants learn to walk. In 1972 Zelazo et al[20] taught parents of ND infants how to elicit the newborn stepping reflex and help their infants practice this pattern daily from the age of two through eight weeks. Practice dramatically increased the frequency and consistency of stepping over the training period compared with the control infants in whom the pattern diminished and ultimately disappeared. Further, although training stopped at 8 weeks the treatment group walked 1 month earlier than the control group.

Some cultures have been way ahead of others with respect to promoting the development of motor skills, including walking. Numerous observational studies of infant development and parenting practices in Africa, South America, and the Indian subcontinent[21] show that children in these societies learn to sit, stand, and walk earlier than American and European children. Their mothers deliberately practiced these skills with their infants. Although parenting practices generally included much direct sensory-motor stimulation, only postures and skills directly targeted were measurably affected. Behaviors, such as crawling, that are not encouraged (and not valued) appear later than in American infants, if at all.[22]

Key to using the stepping reflex as a means to develop walking would be to start this intervention in the perinatal period. For infants with disabilities, this could make the training period quite extended and burdensome for parents, if they are the implementers. But, in 1991 Thelen and Ulrich[23] found an alternative context that could be used later in life. They demonstrated that when supported upright on a small, motorized treadmill ND infants produced alternating steps throughout most of the first year of life. In this situation infants took only a few steps during the first 2 to 3 months and they were of multiple step types: alternating, parallel, single, and double (or stutter steps). Between 3 and 5 months of age all infants shifted into an increasingly stable spontaneous alternating stepping pattern.

Ulrich and colleagues[24,25] followed this study of ND infants with a similar one focused on the response of infants with DS to the treadmill context. By testing infants only once a month on the treadmill, they showed that infants with DS, like ND infants, responded to the treadmill by producing steps, even without the benefit of practice. Like their normally developing peers at developmentally younger ages, infants with DS performed only a few steps and of multiple types. At approximately the point when they began to pull to stand, infants with DS began to respond more consistently with alternating steps. Overall, the median age at which infants with DS began to respond consistently was 14 months.

These data were encouraging because they showed that it was possible to elicit a pattern of behavior that was very similar to the functional skill of walking, but also because this activity is something parents would be able to administer. One of the most important elements in helping parents of infants with disabilities come to grips with their situation is to enable them to take ownership of the progress their children make. The treadmill paradigm provides a structure for parents to follow.

The goal was to test the impact of treadmill practice, administered in the homes, by parents, on the rate of onset of walking in infants with DS. Our primary measures of effectiveness were comparisons between the experimental and control groups on the length of time elapsed between sitting for 30 seconds (requirement for entry into the study) and 1) raising self to stand; 2) walking with help; and 3) walking independently.

METHODS

Study Participants

The study procedures were approved by the Human Subjects Review Committee at Indiana University. Thirty infants with DS were recruited from parent support groups and DS clinics in

Cincinnati, Indianapolis, Ft Wayne, Louisville, and surrounding areas. Only infants with the trisomy 21 form of DS were eligible and parents were required to obtain approval from their infant's pediatrician (and cardiologist, if applicable) before participation in the study. An initial statistical power analysis designed to detect a group difference (α = .05) in age of onset of walking, suggested that 28 participants were required to provide 80% power. Of the 30 participants enrolled none of the parents withdrew before completion. The average age at entry for the total sample was 307.4 days (standard deviation = 58.9). Two infants were of mixed race while the remaining infants were white. Nine of the infants were born with congenital heart disease requiring surgery (7 were in the experimental group). Five infants in the experimental group and 6 in the control group were born before 38 weeks' gestation.

Parents read and discussed a detailed information form about the study before signing a consent form. Infants were randomized into 2 groups: experimental treadmill intervention and control. They began participating in the study when they could demonstrate the ability to sit independently for 30 seconds (item 34 from the *Bayley Scales of Infant Development, Second Edition [BSID-II]*). The ability to sit for 30 seconds is a developmental marker that occurs just before the time when infants with DS begin to respond spontaneously to being supported upright on a small, motorized treadmill by taking some steps.[25] Throughout the course of their participation in the study all infants received biweekly pediatric physical therapy from a registered therapist who also prescribed activities for parents to implement in the home, based on individual needs. During the conduct of this investigation all parents were encouraged to participate in any activity that was prescribed by their health care provider and early intervention team (foot orthotics, eyeglasses, ear tubes, surgery) even if it was perceived to temporarily delay the onset of walking.

Treadmill Intervention

Infants in the treadmill intervention group had custom-engineered treadmills placed in their homes. Parents were trained to position their infants appropriately and implement the treadmill protocol. Parents held their infants upright so the infants' feet were flat on the treadmill belt. When the treadmill was turned on the belt moved the infant's legs backward and tended to cause infants to produce forward stepping patterns (see Fig 1). If the infants did not step or allowed their feet to drag, parents were trained to reposition their children near the front of the belt to maximize their response to the dynamics of the moving support surface. Parents administered the treadmill intervention 8 minutes per day, 5 days per week, until their children demonstrated the ability to walk independently (item 62 on the *BSID-II*). The treadmill belt speed was set at .2 meters per second (.46 miles per hour). During the initial treadmill training sessions infants were on the treadmill for a 1-minute interval followed by a minute of rest. Parents were encouraged to gradually increase the length of the treadmill training interval until they achieved 8 consecutive minutes of practice.

Biweekly Home Visits

A team of researchers visited all participants biweekly throughout the study. Parents maintained a log book that was read by a
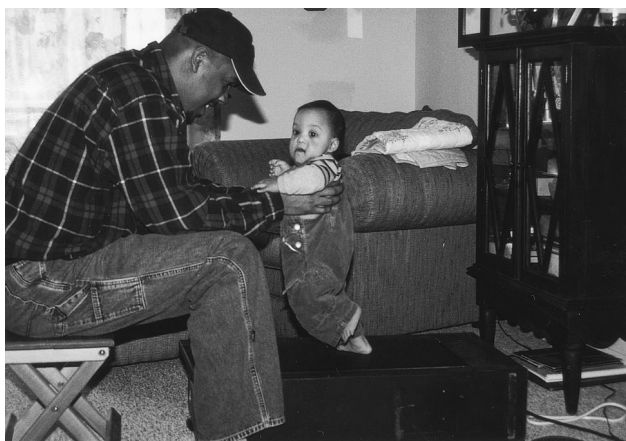

Fig 1. Infant stepping during treadmill training.

research staff member during each visit. Parents were asked to include information regarding the dates and length of their pediatric physical therapy sessions, the general activities that the therapist prescribed for parent implementation, and an estimate of the amount of time the parent spent implementing physical therapy activities at home. Parents were asked to make note of any days that the infant was ill requiring a visit to their physician and the length of the illness. Research staff assessed the ability of infants to perform any new motor milestones (*BSID-II* items). Parents in the experimental group were asked to summarize information in their log on their treadmill training including the date, amount of time the infant was on the treadmill, and comments regarding the infant's response during the training interval. Staff videotaped the experimental infant's response on the treadmill monthly, and recorded the treadmill gauge value that reflected the amount of time the treadmill was in use during the previous 2 weeks.

A memory book was developed for each participant in the study that was kept in the home of the infant. During each visit, staff added information to the book summarizing the infant's progress on their motor development and physical growth (length, weight, and skinfold measures). A Polaroid picture of the infant was inserted into the book monthly.

Monitoring Infants' Growth

Eleven anthropometric measures were taken during the biweekly visits: crown-heel length, thigh and calf lengths, thigh and calf circumferences, foot length and width, thigh, calf, and umbilicus skinfold, and body weight. Recumbent crown-heel length was measured with a static headboard and movable footplate, body aligned, and ankle dorsiflexed to 90°. Thigh length was measured on the right side by marking the greater trochanter and lateral condyle of the femur and measuring the distance with a nonstretchable tape. Calf length was taken by measuring the distance between the condyle of the femur and lateral malleolus. The midpoint of the thigh and calf was where circumferences were taken. Foot length and width was measured while the assistant held the foot off the surface and dorsiflexed the ankle to 90°. Foot length was measured from the heel to the end of the longest toe on the right foot. An anthropometer was used for the measurements of the foot. Thigh and calf skinfolds were taken using a Lange skinfold caliper at the midpoint of each segment length on the medial surface. Horizontal umbilicus skinfold was taken at approximately 1 cm lateral to umbilicus. Weight was taken while the infant was placed in supine on the infant scale. The scale was calibrated before each session. After each measurement, the assistant checked the record of the previous biweekly measurement to determine how much change occurred. If the measurements were largely different, the measurement was retaken to verify accuracy.

Data Analysis

The primary dependent variables of interest were the number of days lapsed between entry into the study and the occurrence of 1) raising up to stand; 2) walking with help; and 3) walking independently (3 steps). Recall that all infants entered the study at the same developmental level, when they could sit independently for 30 seconds. Comparison of group differences in these 3 dependent continuous variables was made by a series of 1-way analyses of variance, subsequent to testing the assumption of homogeneity of variances. A significance level of .05 was used for all analyses. To assist in determining the meaningfulness of the treatment effects, effect size statistics were also calculated for each dependent variable.[26] Before the initiation of the study an effect size of .5 was identified as representing a meaningful treatment indicating that the average participant in the experimental group would be separated from the average participant in the control group by .5 standard deviations. All statistical analyses were derived using the SPSS software system (SPSS, Inc, Chicago, IL).

RESULTS

Participants' Attributes at Study Entry

Infants assigned to the experimental treadmill and control groups were not different at entry in terms of gestational age at birth, corrected chronological age at entry (corrected if born >2 weeks before their due date), *BSID-II* raw motor score, mother's education

level, father's education level, and family income. The groups were different with respect to the number of siblings, with the control group on average having one more sibling than the experimental group. Given that there were no group differences on the 11 anthropometric measures at entry, it appears that the randomization process resulted in producing comparable treatment groups (see Table 1).

Assessment of Treatment Effects on Developmental Outcomes

The primary interest in this trial was to determine if infants with DS who were trained on treadmills would achieve locomotor behaviors valued by parents, earlier. Three behaviors associated with the developmental continuum of upright locomotion were evaluated: raises self to stand (item 52 on the *BSID-II*), walking with help (item 60 on the *BSID-II*), and independent walking (item 62 on the *BSID-II*). The results presented in Table 2 reflect the number of days lapsed from entry into the study until the infant displayed each of the 3 locomotor behaviors. Infants assigned to the treadmill group acquired each of these behaviors faster than the control group infants. For raises self to stand, the group difference was not statistically significant ($P = .09$) but there was a moderate effect size suggesting the groups were meaningfully different.[26] An effect size statistic of .61 indicates the average infant in the experimental group achieved the ability to raise up to a stand .61 standard deviations sooner than the average infant in the control group. For the walks with help behavior, there was a significant difference between the groups ($P = .03$) and a large effect size statistic (.80). Infants in the experimental group demonstrated the ability to walk independently 101 days earlier than those in the control group ($P = .02$). The resulting effect size indicated a large meaningful difference between the groups (.83). The mean chronological age of independent walking for the total sample of 30 infants was 21.9 months. Infants assigned to the group that received treadmill training walked on

TABLE 1. Attributes at Study Entry of Infants Randomized to the Experimental and Control Groups

Attributes	Experimental	Control	P Value
Gestational age at birth (wk)	36.7 (2.25)*	36.4 (2.69)	.71
Chronological age at entry (d)	302.6 (52.6)	312.1 (66.1)	.66
BSID-II motor score†	37.3 (1.05)	37.8 (1.01)	.23
Number of siblings	.5 (.64)	1.5 (1.55)	.04
Mother's education level (y)	15.8 (1.70)	15.0 (1.46)	.18
Father's education level (y)	15.8 (2.21)	15.5 (1.85)	.72
Family income (thousands)	63.3 (24.4)	56.0 (20.6)	.38
Crown-heel length (cm)	69.2 (2.62)	69.6 (2.74)	.66
Weight (kg)	8.2 (.90)	8.1 (.92)	.67
Thigh length (cm)	12.3 (.66)	12.2 (.67)	.54
Calf length (cm)	12.6 (.73)	12.2 (.81)	.13
Foot width (cm)	4.4 (.20)	4.4 (.23)	.34
Foot length (cm)	9.8 (.40)	9.8 (.72)	.87
Mid-thigh circumference (cm)	24.9 (2.12)	24.4 (2.30)	.55
Mid-calf circumference (cm)	17.3 (1.16)	16.8 (1.38)	.33
Umbilicus skinfold (mm)	7.5 (2.30)	6.4 (2.07)	.17
Mid-thigh skinfold (mm)	12.9 (2.87)	11.9 (2.04)	.25
Mid-calf skinfold (mm)	14.5 (2.15)	14.3 (2.25)	.77

* Mean (standard deviation).
† Raw score.

TABLE 2. Differences Between Experimental and Control Groups in Length of Time From Entry into Study to Onset of Selected Locomotor Behaviors

Locomotor Behavior	Experimental Group	Control Group	Mean Difference	P Value	Effect Size
Raises self to stand	134 (69.7)*	194 (115.8)	60	.09	0.61
Walks with help	166 (64.6)	240 (102.7)	73	.03	0.80
Walks independently	300 (86.5)	401 (131.1)	101	.02	0.83

* Mean (standard deviation); unit = days.

average at a chronological age of 19.9 months while the control group walked at 23.9 months.

Assessment of Physical Growth Changes

It was hypothesized that there would be a significant group by time interaction on the 11 anthropomentric variables from entry into the study until walking onset occurred. The interaction would occur if the groups were equal at entry but different at walking onset. This should occur if the infants in the group that received treadmill training walked significantly earlier. A 2-way repeated measures measured analysis of variance was conducted on each of the 11 growth variables using the measure taken at entry and at onset of independent walking. A multivariate F test and effect size statistic (Eta^2) were used to test the group by time interaction effect (Table 3). There were no significant group differences at the time of entry (Table 1). A significant group by time interaction was obtained for the crown-heel and calf lengths, body weight, and foot width and length variables. In addition, medium (.06) and large (.15) effect size statistics[26,27] were obtained for thigh length, thigh and calf circumference, and umbilicus skinfold without reaching statistical significance. With the exception of the umbilicus skinfold, the control group had larger mean values at the time of

TABLE 3. Summary of Group Differences in Anthropometric Variables From Entry* to Walking Onset

Anthropometric Variables	Experimental Group at Walking	Control Group at Walking	P Value†	Eta^2
Crown-heel length (cm)	78.1 (3.5)	81.0 (3.0)	.03	.16
Body weight (kg)	10.1 (1.09)	10.8 (1.6)	.03	.15
Thigh length (cm)	14.9 (.99)	15.4 (1.2)	.09	.10
Calf length (cm)	12.2 (.81)	15.1 (.84)	.05	.13
Foot width (cm)	5.0 (.29)	5.1 (.32)	.06	.12
Foot length (cm)	11.4 (.54)	12.0 (.55)	.01	.21
Thigh circumference (cm)	26.1 (2.09)	26.7 (2.8)	.09	.09
Calf circumference (cm)	17.8 (.97)	18.1 (1.6)	.06	.12
Umbilicus skinfold (mm)	6.9 (1.7)	6.8 (2.3)	.08	.10
Mid-thigh skinfold (mm)	11.6 (1.7)	11.7 (3.4)	.25	.05
Mid-calf skinfold (mm)	12.8 (1.8)	13.2 (2.5)	.22	.05

* Measurements taken at entry are presented in Table 1.
† Based on a multivariate F test for group difference in change from entry to walking onset where significant differences indicate an interaction effect.

walking onset, which is not surprising given that they were also older.

Multiple physical growth variables could influence the age at which an infant walks independently.[28] For example, infants who are leaner might be expected to be able to raise up to standing and support their body weight during walking earlier than infants who are heavier. To determine if the experimental group infants had anthropometric characteristics that enabled them to walk earlier, an analysis of group differences at walking onset was conducted. The age of each infant in the experimental group when he or she began to take 3 independent steps was used to match him or her with an infant in the control group (±1 week). The anthropometric measure that was taken for the experimental group infants nearest to the onset of walking was used to make group comparisons. For example, if infant 1 in the experimental group walked at an age of 550 days, the matched infant in the control group who was also 550 days of age (±1 week) was used as a match. Infants were also matched on gender in all but 2 cases. There were no significant group differences noted on any of the 11 anthropometric variables (Table 4) and none of the effect size statistics reached a meaningful level (.50).

DISCUSSION

The effectiveness of therapeutic interventions applied to children with DS has been a topic of debate.[12,16] The underlying view of this investigation is that to be successful the intervention must target a specific skill. Badke and DiFabio[17] suggested that to improve results in the physical domain the intervention should focus on movement patterns. Furthermore, they claim that practicing movement patterns leads to the improvement and integration of functional motor responses that involve these practiced patterns. The assumption of this study is that the treadmill intervention significantly increases the practice of a specific movement pattern—stepping-that leads to the functional behavior of walking. Previous research has shown that stepping on a

treadmill and walking have many characteristics in common.[29,30,31] Both, the kinematic as well as the kinetic patterns of overground and treadmill walking have been shown to be similar. The treadmill intervention offered repeated opportunities to improve balance, build strength in the lower extremities, and stimulate the neuronal connections that are involved in the generation of independent walking. Developmentally, it has been suggested that sufficient strength and balance are 2 critical requisites for the onset of independent walking.[32,23]

Our intervention may well have been successful because the specific skill of stepping was targeted, via a motorized treadmill. These developmental results show that deliberate practice of alternating steps on a motorized treadmill before independent walking reduced the delay in the onset of this skill in infants with DS. A home-based training of 8 minutes per day, 5 days per week on the treadmill, resulted in a significant positive effect on the development of standing, walking with assistance and walking independently.

Two competing hypotheses for the group effect found in our study were considered. First, the impact of differences in the number of siblings. In our sample, the only attribute that was different at the outset was the number of siblings in the family. Infants in the control group had 1 more sibling compared with infants in the experimental group. A larger number of siblings could have a positive impact on the development of an infant. Abramovitch and colleagues[33] contend that if siblings are not too much older or younger, infants with DS experience supportive challenges and are more motivated to imitate their active siblings. Also, siblings of handicapped children often engage in more parallel and social play and are more nurturing.[34] Together, these results suggest that the initial difference in number of siblings would more likely have represented an advantage in favor of infants in the control group. Therefore, the results presented could not be explained by this attribute.

The second factor that could conceivably affect walking onset is differences in body size as the infants develop. Infants in the control and experimental group had no differences in any of the anthropometric measures taken at the time of entry into the study. Previous research has suggested that leaner infants tend to walk earlier.[28] To ensure that the results were not affected by differences in the body size measures, a comparison was made between the experimental group infants at the onset of independent walking with the closest age-matched child in the control group on each of the anthropometric variables. The results indicated no significant differences between the groups, suggesting that walking onset was not affected by differences in body size between the two groups.

The findings from this investigation support the effectiveness of our early intervention. With these significant results as a starting point, there are several questions that will be addressed in the future. First, does the treadmill intervention have a positive impact on the quality of the gait and future func-

TABLE 4. Group Differences on Anthropometric Variables at the Onset of Walking for the Experimental Group*

Anthropometric Variables	Experimental Group (n = 15)	Control Group (n = 15)	P Value	Effect Size
Crown heel length (cm)	78.12 (3.43)†	78.69 (2.80)	.62	0.18
Weight (lbs)	22.20 (2.32)	22.26 (2.88)	.95	0.02
Thigh length (cm)	14.54 (1.36)	14.80 (1.63)	.64	0.17
Calf length (cm)	14.77 (.84)	14.23 (.71)	.07	0.69
Foot width (cm)	4.98 (.31)	4.86 (.26)	.25	0.43
Foot length (cm)	11.42 (.58)	11.35 (.55)	.75	0.12
Thigh circumference (cm)	25.87 (1.98)	26.11 (2.52)	.77	0.11
Calf circumference (cm)	17.89 (.98)	17.73 (1.30)	.71	0.14
Umbilicus skinfold (mm)	6.73 (1.71)	6.90 (2.41)	.83	0.08
Thigh skinfold (mm)	10.80 (2.23)	11.73 (3.07)	.35	0.35
Calf skinfold (mm)	12.67 (2.08)	13.47 (2.67)	.37	0.34

* At the time infants in the experimental group began to walk independently they were matched with infants in the control group on chronological age to make group comparisons on each anthropometric variable.
† Mean (standard deviation).

tional movement? Most children with DS receive physical therapy and wear foot orthotics because of problems in their gait. Furthermore, by late childhood many children with DS begin to complain about pain in their leg joints when they are moderately active. This could be attributable to misalignments of their leg segments. If the intervention proves to result in better quality of gait, these misalignments might be reduced. Further, research should be conducted to look at the long-term effects of this intervention on the child's ability to negotiate obstacles in their pathway while maintaining dynamic balance. Parents, teachers, and therapists suggest that children with DS are more prone to falls when encountering obstacles in their environment. It will be interesting to see if the positive effects observed in this study at walking onset are maintained as the child enters preschool.

Given the consistent profile of people with DS that reflects congenital heart disease and decreased cardiovascular condition,[35,36] research should be conducted to look at the effects of this intervention on the overall level of physical activity and stamina. It would be expected that an improvement in the cardiovascular system would occur if the treadmill training continues beyond walking onset or is intensified depending on the capacities of the child. Recall that 7 infants in the experimental treadmill-training group were known to have experienced heart surgery during the first year of life. None of these infants demonstrated observable problems while participating in the training. We purposely designed the protocol of training used in this trial (belt speed was .2 m/s for 8 minutes) to minimize intensity. Unfortunately, there is no available literature on exercise training during infancy and therefore, finding the optimal training protocol will require extensive pilot work.

An additional question is the overall effect that enhanced onset of independent locomotion may have in the global development of children with DS. Previous research has demonstrated that the onset of locomotion has positive effects on cognitive and socio-emotional development in normally developing infants as well as infants with disabilities.[6] One might predict that improvement in socio-emotional development could occur because of the increased and recurring one-on-one interaction between the infant and the caregiver throughout the practice sessions. Speech therapists should be consulted for specific recommendations to enhance caregiver interactions while holding the infant on the treadmill.

Lastly, the results of this clinical trial beg the question of whether the treadmill intervention can be used as successfully with other infant populations with locomotor delays, such as infants at risk for cerebral palsy or infants with spina bifida.

CONCLUSION

The developmental evidence generated from this randomized clinical trial involving treadmill training of infants with DS provides support for its use as an early intervention approach to facilitate earlier onset of independent walking. The treadmill protocol, initiated when the infant can sit, offers a structured early intervention that parents can implement at home. Given that most parents of infants with DS want their child to walk independently long before their second birthday, medical professionals should consider encouraging parents to use this skill-specific approach as a supplement to their treatments for the young child with DS. Future studies should focus on manipulating the treadmill training procedures in an attempt to reduce the delay in walking onset more dramatically and to evaluate the impact on the child's gait pattern.

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