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Influences of Treadmill Training on the Motor Development of Infants With and Without Disabilities

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The influence of treadmill training was examined in eight studies including 72 young children with and without disabilities or delays. Treadmill training is an intervention in which young children practice stepping on a motorized treadmill to help improve motor functioning. The reports included mostly experimental and quasi-experimental studies to determine the benefits of the practice on the motor development of infants. Findings from this practice-based research synthesis provided some evidence suggesting the effectiveness of treadmill training for enhancing infant stepping and walking in alternate steps. However, evidence regarding the widespread feasibility of this training for parents has yet to be established.

Purpose

The purpose of this practice-based research synthesis is to ascertain the validity of claims about the influences of treadmill training on the motor development of infants with and without disabilities. The practice is characterized by an infant stepping on a motorized treadmill while supported in an upright position by a harness or an adult. Proponents of treadmill training claim that the practice helps infants at risk for motor delays to walk earlier than they would otherwise (Ulrich, Ulrich, Angulo-Kinzler, & Yun, 2001), improves neuromotor system development (Vereijken & Thelen, 1997), and improves the quality of a child's gait (Ulrich & Barroso, 1999). This synthesis examines existing research on the use of treadmill training with infants and toddlers.

The conduct of the synthesis is guided by a framework that focuses on the degree to which variations in treadmill training are associated with variations in motor development outcomes for infants (Dunst, Trivette, & Cutspec, 2002). This approach to synthesizing research evidence differs from more traditional approaches to integrating research findings by its explicit focus on disentangling and unpacking the characteristics, features, and elements of environmental variables (Babbie, 1995; Bronfenbrenner, 1992) that are associated with behavioral or developmental differences.

Background

The premise of the practice is that early, intensive locomotor training provided before an infant has attained independent walking will result in improved motor skills. One area of research in which the practice has its roots is that of cultural customs of infant handling. Such research indicates that babies from cultures in which parents encourage them to practice standing and walking reach those motor milestones earlier than do infants in cultures where such practice is not specifically encouraged (Super, 1976). A second area of research on which the practice is built is that of newborn reflexes. It has been demonstrated that the stepping reflex present in newborns can be prolonged or elicited in infants when parents provide opportunities for their infant to practice stepping (Zelazo, Zelazo, Cohen, & Zelazo, 1993; Zelazo, Zelazo, & Kolb, 1972). Zelazo et al. (1993) demonstrated that when 6-week-old infants were held so that their feet contact a flat surface and the stepping response was elicited over several weeks, the infants stepped more than infants who did not practice stepping. This work provided empirical support for naturalistic observations that stepping practice on a flat, firm surface can lead to increases in infants' stepping responses (Super, 1976). Building on these two areas of research as a foundation, treadmill training involves a therapist or par-

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ent using a treadmill to elicit infant stepping reflexes and then encouraging infants to practice stepping by providing them with ongoing treadmill opportunities.

Description of the Practice

Treadmill training is an intensive locomotor intervention for infants and young children. The practice is characterized by supporting an infant upright on a small motorized treadmill that is placed on either the floor or a table. The infant's feet are placed flat on the treadmill belt. The treadmill operates at a speed high enough to move the infant's legs backward so that the infant is compelled to take a step forward so as to produce stepping patterns (Ulrich et al., 2001). The infants are either supported by a harness or by an adult and are held above the treadmill in such a way that allows the children to bear as much of their own weight as they would normally, while being provided additional support and balance as necessary (Richards et al., 1997; Ulrich, Ulrich, & Collier, 1992; Vereijken & Thelen, 1997).

Search Strategy

Search Terms

Identification of relevant studies was accomplished using the truncated search terms *treadmill,* as well as the key words *training* and *stepping reflex.* The truncated terms *preschool, kindergarten, neonate, infant, newborn, toddler,* and *child* were used to limit the search results.

Sources

A computer-assisted bibliographic database search was conducted using Psychological Abstracts online (PsycINFO), Educational Resource Information Center (ERIC), Social Science Citation Index (SSCI), MEDLINE, Cochrane Database of Systematic Reviews (Cochrane DSR), Cochrane Database of Abstracts of Reviews of Effects (Cochrane DARE), Cochrane Controlled Trials Register (Cochrane CTR), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Health Source: Nursing/Academic Edition, Dissertation Abstracts International, OCLC PapersFirst, OCLC ProceedingsFirst, National Technical Information Service (NTIS), REHABDATA, CIRRIE, InfoTrac Expanded Academic ASAP, Social Sciences Index, Education Index, WorldCat, and Academic Search Elite. A Web search using Google was also conducted. In addition, hand searches of reference sections of treadmill training investigations were also reviewed for other relevant empirical work.

Selection Criteria

The primary inclusion criterion was that studies investigated the influences of treadmill training on the motor development of young children. Therefore, the search was limited to studies investigating outcomes for children 6 years of age or younger; and studies involving primarily older participants were excluded (Lotan, Isakov, Kessel, & Merrick, 2004; Lotan, Isakov, & Merrick, 2004; Schindl, Forstner, Kern, & Hesse, 2000).

Search Results

Eight reports met the inclusion criteria. Table 1 includes selected characteristics of the study participants. Table 2 includes characteristics of the treadmill-training intervention. Table 3 includes characteristics of the study designs.

Participants

The eight studies include 72 participants. The mean age of study participants was 11 months (Range: 3-24 months). Nine infants were reported not to have any disability or delay, while 58 infants were reported to have Down syndrome, four were reported to have cerebral palsy, and one infant was reported to have been born prematurely with an intraventricular hemorrhage.

Practice Characteristics

All of the investigators provided information regarding the treadmill used during training. Investigators for seven of the studies (88%) reported using small, motorized treadmills; whereas in the eighth study, a standard-sized motorized treadmill was used (Auxter et al.,1986). Infants were supported on the treadmill by the experimenter (four studies), by the parent (one study), by the experimenter and parent at different times (one study), or by a harness (one study). The participant in one study was not supported in any manner because he was able to bear weight without assistance. Investigators from four studies (50%) reported that the participants' diapers and clothes were removed during the treadmill sessions. The other four investigators did not specify whether or not the participants were clothed during sessions.

Investigators of seven studies (88%) reported the treadmill speeds used during sessions. The mean treadmill speed at the beginning of training was 19 cm per second. The mean treadmill speed at the conclusion of training (in the two studies that increased speed) was 27 cm per second. Training sessions lasted an average of 6.6 minutes across the seven studies reporting session length, with their trials ranging from 2.2–8 minutes in length. Participants had an average of 33 sessions across the five studies that provided that information. In three studies, the training sessions occurred until the child reached a certain criterion, such as taking three steps independently. On average, participants averaged four sessions per week in the seven studies that reported session frequency.

Treatment Fidelity

Some information regarding the fidelity of implementation of the treadmill intervention was reported in four studies. Measures of treatment fidelity included therapist

and parent logs, videotapes of the intervention session, verbal descriptions, and a treadmill gauge or timer and buzzer to measure the length of the treadmill intervention. The remaining four studies reported the length of time infants received the intervention and treadmill speeds used during the intervention, but did not explicitly provide information regarding how the length of time was measured or the validity of the speeds was assessed.

Research Designs

Investigators for three studies reported the results of single-subject research studies. Three other sets of investigators reported the results of a single-group longitudinal study in which all children received treadmill training, with one set of investigators assigning participants to either low or high treadmill-training conditions (Ulrich & Barroso, 1999)**.** Two sets of investigators reported the results of randomized experimental studies with comparison participants (Ulrich et al., 2001; Vereijken & Thelen, 1997) In these two studies, comparison group children received no treadmill training and/or were supported on a stationary treadmill.

Outcomes

All investigators reported improvements in participants' motor skills as a result of treadmill training. Reported benefits included an increase in number of steps taken, an increased ability to take alternate steps, and improvements in gait. Three investigators reported that infants with disabilities who received treadmill training began independent walking earlier than expected. In one study, the investigator reported that treadmill training increased the free running speed of a child without disabilities.

Synthesis Findings

Table 4 shows the findings from the studies as reported by the investigators. The relationship between treadmill training and the outcomes constituting the focus of investigation was ascertained in two ways. First, the statistical or functional relationship between treadmill training and the outcomes of interest as reported by investigators was examined. Second, the magnitude of effect (Cohen's *d*) between treadmill training and motor development was used as an index of the effect size estimates or degree of association between the independent and dependent variables. This was done using the guidelines described in Dunst, Hamby, and Trivette (2004)**.** Sufficient information was available in four studies to calculate Cohen's *d* effect sizes.

Overall, investigators reported developmental gains in the walking and alternate stepping of infants with and without disabilities. Improvement in the infants' gait quality was also reported by several investigators.

Effect sizes of posttest differences for motor outcomes were calculated for all studies for which data were available (Table 4). The number of instances where the effect sizes for the relationship between the treadmill training and motor outcomes exceeded a quarter of a standard deviation (.25) was ascertained. Of the nine effect sizes that were calculated across the studies, 100% exceeded the criterion. The average effect size for the group studies was 1.96 and the median effect size across all studies was 2.21, indicating a discernable relationship between the use of treadmill training and infant motor development.

Rival Explanations

It is possible that certain threats to internal validity (Campbell & Stanley, 1963; Cook & Campbell, 1979) and rival explanations (Yin, 2000) for observed effects could explain the study findings reported above. For example, factors such as testing and instrumentation may be likely explanations for observed outcomes. Nonintrusive observational assessments were used to measure infant motor behavior in six (75%) of the studies. While observational assessments could result in observer or rater bias, this likelihood of observer bias is minimized by the fact that four of the six studies (67%) employed at least two independent observational data coders. The possibility of bias is also minimized by the fact that two investigators supplemented their observational assessments with rating scales of motor development and two others assessed outcomes through standardized measures.

Small sample size is a potential problem in all of the group-design studies (range: 4-15 infants in the experimental condition). However, robust statistical results were reported by investigators and large effect sizes were calculated for reported outcomes. One investigator conducted a statistical analysis indicating his sample size (Experimental n = 15) was large enough to detect statistically significant differences.

Maturation could be an alternative explanation for the reported outcomes in six (75%) of these studies and was identified as a rival explanation by one group of authors (Ulrich & Barroso, 1999). Given that the training sessions in the five studies occurred over several weeks or months, observed motor gains could be the result of the infants' natural developmental progression and be unrelated to the treadmill intervention. The age of independent walking's onset and the pattern with which infants acquire motor milestones are highly variable (Darrah, Redfern, Maguire, Beaulne, & Watt, 1998), making it especially difficult to distinguish between treadmill training's effects and maturation in these studies due to their small sample sizes. This concern is slightly mitigated, however, by the two studies with control groups whose results indicate improved motor development in the treadmill-training condition. Furthermore, other investigators compared their

results to the average age at which children with the same disabilities walked independently, finding that those who received the treadmill training walked at an earlier age.

A problem in three of the studies (38%) was multiple treatment interference**,** as the participants in those studies who received treadmill training were simultaneously receiving physical therapy interventions to improve motor development. The schedule of these additional physical therapy sessions ranged from occurring daily to occurring weekly. In at least two of the three studies, the treadmill training was implemented within each therapy session in conjunction with other interventions. Two of the eight studies (Ulrich et al., 2001; Vereijken & Thelen, 1997) included a comparison group to control for multiple treatment interference, with results indicating that the treadmill-training condition is preferable to the control condition.

In summary, the studies included in this synthesis controlled major threats to internal validity and rival hypotheses to some extent. That the plausibility of rival explanations or validity threats were somewhat minimized suggests that the observed outcomes may be attributable to the fact that the infants received the treadmill-training intervention.

Conclusions

The findings from this practice-based research synthesis indicate that treadmill training may be a potentially effective method for enhancing the motor development of infants with and without disabilities. This conclusion should be interpreted with caution, however, given that investigators did not fully control for potential rival hypotheses.

A *Bottomlines* (Vol. 4, No. 5) report that describes the major findings from this research synthesis in nontechnical, user-friendly language has been developed to supplement this *Bridges* report. The *Bottomlines* summarizes what we know about the use of treadmill training with infants and is written specifically for parents and practitioners. Both the *Bridges* and *Bottomlines* reports are available in electronic versions at our Web site (www.researchtopractice.info).

Implications for Practice

The findings from this research synthesis have implications for practice. The findings suggest that treadmill training may be one method for enhancing infant motor skills, especially for pre-walking infants with disabilities. Furthermore, it appears that treadmill training is an intervention that can be easily implemented by parents and practitioners if a treadmill is available; it also appears that infants enjoy treadmill stepping (Vereijken & Thelen, 1997). However, one factor that needs to be considered is the widespread feasibility of implementing treadmill training. In all but one of the studies, the treadmill used was a small motorized treadmill that was specifically designed for the studies. While some of the investigators suggest that a commercially available, full-size treadmill operating at slow speeds would work as well as the small ones used in their studies, there is no research evidence to support this contention, nor is there any evidence regarding the extent to which obtaining and using such a device would be practical for many parents. Based on past work regarding infants' stepping reflexes (Zelazo et al., 1993; Zelazo et al., 1972), it may be the case that adults can just as well provide infants with opportunities to practice the stepping reflex on a stable surface as a practical, low-cost alternative to using a treadmill. However, such an approach needs further investigation. While treadmill training shows promise as an intervention practice to improve the motor development of infants with motor delays, more evidence regarding the practical nature of this intervention is necessary before this practice can be recommended.

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Table 1
Characteristics of the Study Participants

Study	Sample Size	Gender		Mean Age (months)	Diagnosis
		M	F		
Auxter et al. (1986)	1	1	0	13	Typically developing
Bodkin et al. (2003)	1	1	0	8	Grade III intraventricular hemorrhage Born preterm
Richards et al. (1997)	4	1	3	24	Spastic cerebral palsy
Ulrich & Barroso (1999)	12	NR		10	Down syndrome (Trisomy 21)
Ulrich et al. (2001)	E = 15 C = 15	NR		9.9	Down syndrome (Trisomy 21)
Ulrich et al. (1992)	7	3	4	11	Down syndrome (Trisomy 21 and mosaic subtype)
Ulrich et al. (1995)	7	3	4	9	Down syndrome (Trisomy 21)
Vereijken & Thelen (1997)	E = 6 C = 4	6	4	4	Typically developing
Total	72	15	15	11.1	

E = Experimental
C = Control
NR = Not reported

Table 2
Characteristics of the Intervention

Study	Participant Support During Training	Treadmill Speed (beginning) (cm/s)	Treadmill Speed (ending) (cm/s)	Session Length (minutes)	Session Frequency (weekly)	Total Number of Sessions
Auxter et al. (1986)	Not supported	57	106	4	2	9
Bodkin et al. (2003)	Experimenter or mother	15	15	4.4	3	69
Richards et al. (1997)	Harness	7	70	45	4	64
Ulrich & Barroso (1999)	Experimenter	NR	NR	Group 1: 8 Group 2: Sequentially increased	5	Until the child could take 3 steps independently
Ulrich et al. (2001)	Parent	20	20	8	5	Until the child could walk independently
Ulrich et al. (1992)	Experimenter	10 , 15 , 20	10 , 15 , 20	4	NR	1
Ulrich et al. (1995)	Experimenter	10 , 15 , 20	10 , 15 , 20	3	1x per month	Until the child could produce alternating steps 3 sessions in a row
Vereijken & Thelen (1997)	Experimenter	Group1: 26 Group 2: 14 Control: 0	Group1: 26 Group 2: 14 Control: 0	NR	4	16

NR = Not reported

Table 3
Study Design Characteristics

Study	Research Design	Control-Group Intervention	Random Assignment	Treatment Fidelity Data	Measures
Auxter et al. (1986)	Single-subject	-	No	No	Treadmill speed
Bodkin et al. (2003)	Single-subject	-	No	Yes	AIMS[1], Videotape analysis of infant stepping
Richards et al. (1997)	Single-subject	-	No	No	GMFM[2], SWAPS[3], Videographic test
Ulrich & Barroso (1999)	One group pretest/posttest	Typical walking age for infants with Down syndrome	No	No	GaitRite and Peak motion analysis system
Ulrich et al. (2001)	Randomized experimental	No treadmill training	Yes	Yes	BSID-II[5]
Ulrich et al. (1992)	One group pretest/posttest	-	No	Yes	Videotape analysis of infant stepping
Ulrich et al. (1995)	One group pretest/posttest	-	No	Yes	BSID[4], Videotape analysis of infant stepping
Vereijken & Thelen(1997)	Randomized experimental	No treadmill training	Yes	No	Videotape analysis of infant stepping

[1]Alberta Infant Motor Scale
[2] Gross Motor Function Measure
[3]Supported Walker Ambulation Performance Scale
[4]Bayles Scales of Infant Development, motor scale
[5]Bayles Scales of Infant Development II

Table 4
Major Study Findings

Study	Major Findings	Effect Size	Rival Hypothesis
Auxter et al. (1986)	Treadmill training increased running speed and increments of step size.	-	Maturation
Bodkin et al. (2003)	Treadmill training increased stepping.	3.2	Maturation
	Treadmill training increased number of alternating steps.	28.9	Multiple treatment interference
Richards et al. (1997)	Treadmill training improved the quality of gait.	-	Maturation Multiple treatment interference
Ulrich & Barroso (1999)	Infants in both treadmill-training conditions walked sooner than the typical age for those with Down syndrome. Infants in the high-speed group walked sooner than infants in the low-speed group.	-	Maturation
Ulrich et al. (2001)	Treadmill group was earlier to raise self to standing.	.61	
	Treadmill group was earlier to walk with help.	.80	
	Treadmill group was earlier to walk independently.	.83	
Ulrich et al. (1992)	Infants produced alternating steps only during the treadmill-training phases.	Slow: 2.68 Medium: 2.21 Fast: 2.50	
Ulrich et al. (1995)	Participants were able to produce alternate stepping on a treadmill before they could walk independently.	-	Maturation Multiple treatment interference
Vereijken & Thelen (1997)	Treadmill training resulted in significantly more steps than in the control group.	4.13	Instrumentation
Average Percent		5.09	