Review

Does horseback riding therapy or therapist-directed hippotherapy rehabilitate children with cerebral palsy?

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Quantitative (not qualitative) studies were sought investigating whether horseback riding used as therapy improves gross motor function in children with cerebral palsy (CP). Eleven published studies on instructor-directed, recreational horseback riding therapy (HBRT) and licensed-therapist-directed hippotherapy were identified, reviewed, and summarized for research design, methodological quality, therapy regimen, internal/external validity, results, and authors' conclusions. Methodological quality was moderate to good for all studies; some studies were limited by small sample size or lack of non-riding controls. HBRT improved gross motor function in five of six studies (one study was inconclusive); hippotherapy improved gross motor function in all five studies. The studies found that during HBRT and hippotherapy: (1) the three-dimensional, reciprocal movement of the walking horse produced normalized pelvic movement in the rider, closely resembling pelvic movement during ambulation in individuals without disability; (2) the sensation of smooth, rhythmical movements made by the horse improved co-contraction, joint stability, and weight shift, as well as postural and equilibrium responses; and (3) that HBRT and hippotherapy improved dynamic postural stabilization, recovery from perturbations, and anticipatory and feedback postural control. The evidence suggests that HBRT and hippotherapy are individually efficacious, and are both medically indicated as therapy for gross motor rehabilitation in children with CP. Recommendations for future research are discussed.

This systematic literature review investigates whether horseback riding used as therapy objectively rehabilitates children with cerebral palsy (CP) by producing measurable improvements in gross motor function. According to the International Workshop on Definition and Classification of Cerebral Palsy, CP is defined in terms of motor features and effects on function, as follows: 'Cerebral palsy describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain.'[1] The purpose of this review of research evidence is to determine whether clinicians are justified in recommending horseback riding as therapy for the gross motor rehabilitation of children with CP.

Methods

TREATMENT

Instructor-directed, recreational horseback riding therapy (HBRT) and licensed-therapist-directed hippotherapy use differing modalities of horseback riding as therapy. HBRT is conducted by non-therapist riding instructors and assistants based upon their training and knowledge of the riders' disabilities and of methods for safely using therapy-trained horses.[2] As a treatment, HBRT comprises procedures, precautions, contraindications, and comprehensive lesson plans followed by HBRT instructors and assistants; these procedures are described in the North American Riding for the Handicapped Association's (NARHA) Curriculum for Riding Therapy, the NARHA Operating Center Standards and Accreditation,[3] and in the medical literature.[2,4–8] Sterba et al.[2] describe how the HBRT instructor selects target objectives based on the child's individual physical needs, encouraging the development of sensorimotor and perceptual-motor skills by following the

Developmental Riding Therapy methods of Spink.[9] The rider undergoing HBRT is directed by the instructor and aided by the side-walker(s) who offer as much assistance as necessary, while still being least-restrictive to the rider. The rider performs activities such as touching various parts of the horse's body (e.g. the mane, neck, flank, back) or reaching for an object (e.g. ball or ring), which involves crossing the midline while maintaining appropriate balance and posture. The horse may initially remain still for these activities then begin a slow and steady walk with the rider comfortably lying prone, supine, or sitting upright on a warm horse blanket using a vaulting surcingle as a handhold. When using a saddle, the rider may either sit or stand up using specially designed stirrups, attempting proper postural alignment. The rider imitates movements demonstrated by the nearby instructor (e.g. arms abducted or placed overhead; bilateral arm circles, forward then backward; raising and lowering a stick held with both hands). While the horse is being guided safely by the lead-walker using a lead-line attached to the horse's halter, the rider is encouraged to toss beanbags into bins, place large rings on top of cones, or simulate steering the horse using reins attached to the halter or horse's bit. As the therapy progresses less support is provided by the side-walker(s). Exercises are focused on progressively challenging the rider's ability to stretch and move while maintaining balance and posture in all body positions during the horse's slow, steady gait.

Hippotherapy (from the Greek word *hippos* meaning horse), on the other hand, is treatment performed on the horse under the direction of a licensed health professional (e.g. physical therapists, occupational therapists, physical and occupational therapy assistants, speech-language pathologists, and others). The movement of the horse is used as a therapeutic intervention or tool by the therapist.[10] During hippotherapy, the therapist addresses impairments, functional limitations, and disabilities in patients with neuromuscular dysfunction, including CP,[7,11] focusing on improving walking ability and related gross motor functions of posture, balance, and mobility.[5]

DATABASES

Using library and internet databases, studies for this literature review were sought which investigated the effect of HBRT and hippotherapy on gross motor function in children with CP. Similar keywords to 'HBRT' and 'hippotherapy' found in the literature were also used in all literature searches (e.g. 'developmental riding therapy', 'equine-movement therapy', 'riding therapy', 'riding for the disabled', 'therapeutic horseback riding', and 'therapeutic riding'). These literature searches were also linked to other descriptive terms (e.g. 'cerebral palsy', 'exercise therapy', 'horseback riding', 'horses', 'physical therapy techniques', 'recreational therapy', 'rehabilitation', and 'therapeutic exercise').

Using 'HBRT' and 'hippotherapy' (and hereafter, all keywords and descriptive terms listed above) no literature review was found searching the Cochrane Library (http://www.update-software.com/publications/cochrane) using Update Software's CD-ROM version and Wiley and Sons Internet version of the Cochrane Library or the Centre for Reviews and Dissemination, Database of Abstracts of Reviews of Effects (DARE; http://www.york.ac.uk/inst/crd/darehp.htm).

Next, four primary databases were searched for all quantitative research articles investigating the effect of HBRT and hippotherapy upon gross motor function in children with CP. These databases included: Ovid MEDLINE 1966 to Present with Daily Update; Journals@Ovid Full Text; Cumulative Index to Nursing and Allied Health Literature (CINAHL); and the National Library of Medicine's journal literature search system (PubMed).

SEARCH METHOD

In order to identify clinically relevant, high-quality, current research evidence, all literature searches were confined to quantitative studies published in English over the past 25 years (January 1981 to December 2005). Every article identified by these various searches had its reference list carefully reviewed for any additional articles (including those published before 1981) which investigated the effect of horseback riding on gross motor function in children with CP.

REVIEW METHOD

Inclusion criteria for the selection of research studies included those published articles (not abstracts), which: (1) used a quantitative (not qualitative) study design; (2) investigated the effects of horseback riding on gross motor function; and (3) studied children with CP.

Two methods were chosen to assess each article critically. First, the quality of each identified article's research design type was determined using Guidelines for Critical Review Form – Quantitative Studies by Law et al.[12] (Table I). As defined by Law et al.,[12] there are seven research design types, ranging from highest to lowest quality: randomized controlled (or clinical) trial (RCT); cohort design; single case design; before–after design; case control design; cross-sectional design; and case study design. These seven design types are explained below for each article identified in the literature search.

Second, each selected article was critically evaluated for its methodological quality (MQ) using the Critical Review Form – Quantitative Studies and the Guidelines for Critical Review Form – Quantitative Studies by Law et al.[12] This method was chosen as a tool to evaluate each article under the following main categories: study purpose, literature review, study design,

Table I: Methodological quality of research articles: Critical Review Form – Quantitative Studies[12]

Critical Review Components:
1. Purpose clearly stated?
2. Relevant background literature reviewed?
3. Design appropriate for study question?
4. Absence of any bias (sampling, intervention, or measurement) influencing results?
5. Sample described in detail?
6. Sample size justified?
7. Informed consent obtained?
8. Outcome measures reliable?
9. Outcome measures valid?
10. Intervention described in detail?
11. Results reported with statistical significance?
12. Analysis methods appropriate?
13. Significant differences between groups clinically meaningful?
14. Conclusions appropriate from results?
15. Implications of results influencing clinical practice reported?
16. Main limitations or biases of study discussed?

sample, outcomes, intervention, results, conclusion and clinical implications. The overall quality of each article was assessed using 16 closed-ended questions evaluating internal and external validity of the study and its findings and conclusions.[12] These 16 questions were scored as either 1 (completely fulfills the criterion) or 0 (does not fulfill the criterion). Scores for all 16 questions were totaled for each article itemized (Table II). A maximum score of 16 indicated excellent MQ.

Results

Fifty-one papers were identified. Following screening for inclusion criteria and removal of those articles sourced from more than one database, 11 papers were identified for this critical literature review.[2,4–8,13–17] The 40 papers that were excluded included historical reviews, descriptive (qualitative) reviews, studies not measuring gross motor function, and quantitative studies on participants not with CP.

None of the studies identified met the highest quality of research design (RCT). The research design quality of the 11 articles, according to the research design criteria,[12] ranged from moderately high to low, as follows: RCT, n=0; cohort design, n=3; single case design, n=1; before–after design, n=4; case control design, n=0; cross-sectional design, n=0; and case study design, n=3.

METHODOLOGICAL QUALITY

MQ of the 11 papers was moderate to good (mean 9.8 [SD 3.6]), out of a possible maximum score of 16 (see Tables I and II); no article scored a maximum 16. Highest scores for MQ were determined for studies by Sterba et al.[2] (15) and McGibbon et al.[5] (14), both of which were single case designs. Only the four studies by MacPhail et al.,[6] Sterba et al.,[2] Cherng et al.,[8] and Casady and Nichols-Larsen[17] fulfilled criterion 4[12] (absence of any bias-sampling, intervention, or measurements); no study fulfilled criterion 6[12] (sample size justified; Table II).

EFFECTIVENESS OF HBRT AND HIPPOTHERAPY

Of the 11 articles reviewed, six investigated HBRT[2,4,6–8,13] and five investigated hippotherapy.[5,14–17] There was no article comparing both HBRT and hippotherapy in the same study. Of the six articles studying HBRT, five[2,6–8,13] concluded that HBRT was effective in improving gross motor function. One article on HBRT[4] did not show a significant change in gross motor function, concluding that further research was indicated. All five articles on hippotherapy[5,14–17] concluded that hippotherapy was effective in improving gross motor function.

The six articles studying HBRT and five articles studying hippotherapy are summarized and critically reviewed below on the basis of their therapy regimen, MQ, key results, and authors' conclusions about the efficacy of horseback riding as therapy to improve gross motor function.

STUDIES ON HBRT

(1) Fox et al.:[13] (n=19; 6wks, 90–120min session, once/wk; before–after design; no measurements during treatment; no control group; MQ 5/16). Using a novel balance beam apparatus (measuring relative [%] changes in range of body movements and strength against resistance from loaded springs), HBRT collectively improved balance and coordination of hands, arms, and legs (7.2%), strength of arms (8.1%), strength of legs (13.8%), and sitting posture (18.0%) in 19 developmentally delayed children (including an unspecified number of children with CP); no statistics were reported. The authors' concluded HBRT improved balance, coordination, strength, and sitting posture in developmentally delayed children.

(2) MacKinnon et al.:[4] (n=19; 26wks, 1hr session, once/wk; cohort design, conducted prospectively with a control group; MQ 5/16). Nineteen children with spastic CP (mild [ambulatory] or severe [non-ambulatory or ambulatory with devices]) were non-randomly assigned to HBRT or the non-rider control in four groups as follows: Group 1: mild CP-HBRT (n=5); Group 2: mild CP-control, non-HBRT (n=5); Group 3: moderate CP-HBRT (n=5); and Group 4: moderate CP-control (n=4). Gross Motor Function Measure (GMFM)[18,19] did not change for any group; absolute GMFM values were not reported. The authors commented that small sample size and variations in age and severity of CP within the small groups contributed to the non-significant results. The authors stated that their study was inconclusive, indicating the need for further research.

(3) MacPhail et al.:[6] (n=6 with CP, 7 without CP; 10wks, 1hr session, once/wk; cohort design; MQ 11/16). The horses' pelvic movement during walking and the riders' corresponding

Table II: Results of methodological quality of research articles: Critical Review Form – Quantitative Studies[12]

Studies	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*Total*
Bertoti[14]	1	1	1	0	1	0	1	1	0	1	1	1	1	1	1	1	13
Bertoti[15]	1	1	0	0	1	0	0	0	0	1	0	0	1	1	0	1	7
Casady and Nichols-Larsen[17]	1	1	1	0	1	0	1	1	1	0	1	1	0	0	1	1	11
Cherng et al.[8]	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	0	12
Fox et al.[13]	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	5
Haehl et al.[16]	1	1	1	0	1	0	0	0	0	0	0	0	0	1	0	1	6
MacKinnon et al.[4]	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	5
MacPhail et al.[6]	1	1	1	1	1	0	1	0	0	1	0	1	1	1	0	1	11
McGibbon et al.[5]	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	14
Sterba et al.[2]	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	15
Winchester et al.[7]	1	1	1	0	1	0	1	1	1	1	1	0	0	0	0	0	9
x=mean total	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9.8
SD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3.6

torso movement during riding (called lateral trunk displacement) was not a simple, side-to-side, rocking sinusoidal frequency movement. The observed dual sinusoidal frequency movement of horseback riding subjected all riders to a more complicated pattern of pelvic and truncal displacement, placing a greater demand on the riders' automatic postural responses and, thereby, simulating a normal walking pattern. The riders' lateral trunk displacement was less in seven non-disabled riders (controls) than observed in the six riders with CP: (non-disabled riders=5.8° [SD 0.5] vs riders with CP=10.2° [SD 2.2]; $p<0.01$). Compared to the normal range of torso movement (defined as being within 2SD of the mean torso movement for non-disabled riders [controls]), riders with diplegia ($n=3$) had a greater (i.e. improved) equilibrium reaction of their torso to horses' pelvic movement compared with riders with quadriplegia CP ($n=3$; diplegia=67–75% of time vs quadriplegia=8–36% of time; no statistical analysis performed). The authors concluded that HBRT facilitates normalized torso equilibrium reaction to the horses' pelvic movement to a greater degree in children with diplegia than in those with quadriplegia.

(4) Winchester et al.:[7] ($n=7$; 7wks, 1hr session, once/wk; before–after design; MQ 9/16). GMFM summed scores (GMFM Dimensions B [Sitting], C [Crawling and Kneeling], D [Standing], E [Walking, Running, Jumping], excluding A [Lying and Rolling]) improved by 17.9% ($p<0.01$), remaining elevated 7 weeks post-HBRT (16.8%; $p<0.01$) for all seven children with various developmental delays (CP, $n=2$; Down syndrome, $n=2$; Down syndrome and autism, $n=1$; spina bifida, $n=1$; traumatic brain injury, $n=1$); GMFM data for children with CP was not reported. The authors concluded that HBRT might improve gross motor function in children with developmental delay, an effect which remains elevated after HBRT ceases.

(5) Sterba et al.:[2] ($n=17$; 18wks, 1hr session, once/wk; single case design performed prospectively with each participant serving as their own control with multiple GMFM measurements made during the treatment; MQ 15/16). GMFM Dimension E (GMFM- E; Walking, Running, Jumping) improved by 8.5% ($p<0.03$), remaining elevated 6 weeks post-HBRT, 1.8% ($p<0.03$). GMFM Total Score improved 7.6% ($p<0.04$) in 17 children with spastic CP. The authors concluded that as HBRT improved GMFM Total and GMFM-E scores, which persisted 6 weeks post-HBRT, HBRT should be recommended as sports therapy for the gross motor rehabilitation of children with CP.

(6) Cherng et al.:[8] on HBRT ($n=14$; 16wks, 40min session, twice/wk; a cohort design, described methodologically by authors as 'within participant repeated-measures design'; MQ 12/16). Fourteen children with spastic CP were divided (non-randomly) as having mild CP ($n=6$; ambulatory) or severe CP ($n=8$; non-ambulatory or ambulatory with devices) and were also subdivided (non-randomly) into two groups of unequal size: Group A ($n=9$) received HBRT for the first 16 weeks. Group B ($n=5$) comprised non-riding controls, who began HBRT for the second 16-week period. Following 16 weeks of HBRT, GMFM-E (Walking, Running, Jumping) improved by 10% ($p<0.01$) and GMFM Total Score improved by 5% ($p<0.01$; for all 14 children with these changes [%] determined from authors' Fig. 1; absolute values of these GMFM data not reported). The authors commented that improvements in GMFM-E might last for 16 weeks post-HBRT; no statistics were reported for these GMFM data during the 16-week recovery phase. The authors reasoned that a significant effect of HBRT upon GMFM-E and Total Score not interacting with either Groups A versus B, or for mild versus severe CP, might have been due to small sample size. The authors concluded that HBRT might be beneficial for some children with spastic CP.

STUDIES ON HIPPOTHERAPY

(1) Bertoti:[14] ($n=11$; 10wks, 60min session, twice/wk; before–after research design; author conducted the hippotherapy; MQ 13/16). Independent therapists used a novel test objectively scoring posture (4-point scale: 0, severe limitations; 1, moderate limitations; 2, minimal limitations; and 3, symmetrical, normal movement) for five measurements of posture (head/neck, shoulder/scapula, trunk, spine, and pelvis), reporting good interrater reliability. Hippotherapy improved posture ($p<0.05$); 37.9% as determined from author's Table 2; post-hippotherapy recovery data on posture was not collected. The author concluded children with spastic CP improved posture during a period (10wks) of hippotherapy.

(2) Bertoti:[15] ($n=1$; 6wks, 60min session, twice/wk; case study design, hippotherapy conducted by an independent therapist, not the author; MQ 7/16). The measured weight bearing of arms and legs in one, 2½-year-old child with hemiplegic CP. Weight bearing improved in both sides, arms and legs, but more so on the hemiplegic side; no statistics were reported for weight-bearing data. The author concluded that hippotherapy could be recommended to promote symmetry, equalize weight bearing, and facilitate weight shift in children with hemiplegia.

(3) McGibbon et al.:[5] ($n=5$; 8wks, 30min session twice/wk; case study design, hippotherapy conducted by the author and one trained assistant; MQ 14/16). GMFM-E (Walking, Running, Jumping) improved ($p<0.05$) in five children with spastic CP. Data revealed GMFM-E improved by 6.4%; no GMFM-E measurements were made during the recovery, post-hippotherapy period. The authors' concluded that hippotherapy might improve gross motor function in children with CP.

(4) Haehl et al.:[16] ($n=2$; 12wks, 1hr session once/wk; case study design; MQ 6/16). Using kinematic measurements from videography, two children with spastic CP improved coordination (upper and lower trunk; lower trunk and back); one child improved functional mobility (Pediatric Evaluation of Disability Inventory [PEDI]);[20] no statistical analysis was performed. The authors concluded that hippotherapy improved trunk coordination and functional mobility.

(5) Casady and Nichols-Larsen:[17] ($n=10$; 10wks, 45-min session once/wk; before–after research design, primary author conducted the hippotherapy; MQ 11/16). Independent therapists used the GMFM and the PEDI with good interrater reliability in 10 children with CP. GMFM and PEDI did not change 10 weeks before hippotherapy (or during recovery 10wks following the 10wk hippotherapy period). Significant changes in GMFM Dimension C (Crawling and Kneeling), GMFM Total Score, PEDI Social Score, and PEDI Total Score were identified during the 10-week treatment phase; no percentage change was reported. The authors concluded hippotherapy conducted by therapists with training and experience should be used as a treatment strategy to improve functional outcomes in children with CP.

Discussion

There is a growing body of knowledge demonstrating the

efficacy of horseback riding used as therapy in either HBRT or hippotherapy to improve gross motor function in children with CP. Five of six studies on HBRT[2,6,7,8,13] demonstrated improvements in gross motor function while one study[4] was inconclusive due to small sample size and high variability in GMFM data. All five studies on hippotherapy demonstrated significant improvements in gross motor function in children with CP.[5,14–17]

The overall MQ of these 11 studies on HBRT and hippotherapy was moderate to good (9.8 out of a maximum 16 possible score; Table II). The primary limitations seen in some of these studies were small sample sizes and lack of a control, non-riding group.

Physiological mechanisms reported for HBRT and hippotherapy for improving gross motor function are related to the rider responding to the three-dimensional, reciprocal movement of the walking horse. Both HBRT and hippotherapy produce pelvic movements in the rider which closely resemble pelvic movements during ambulation in able-bodied individuals with no gross motor disability.[6,9,14,21,22] During HBRT and hippotherapy, variations in the horse's stride, velocity, and direction facilitate righting and equilibrium responses in the rider. The rider's center of gravity is displaced, facilitating dynamic postural stabilization and recovery from perturbations,[5,23–26] promoting anticipatory and feedback postural control.[5,27] During hippotherapy and HBRT the sensation of smooth, rhythmical movements made by the horse facilitate and improve co-contraction, joint stability, weight shift, and postural and equilibrium responses, resulting in improvements in gross motor function in children with CP.[2,5–8,13–17]

Further research is recommended with larger sample sizes and matched, non-riding controls, to investigate more fully the positive effects of HBRT and hippotherapy on gross motor function. Investigations should be expanded to study CP of all types (e.g. spastic, dystonic, and mixed), distribution (e.g. diplegia, hemiplegia, and quadriplegia), aetiology (hypoxia, drugs and toxins, infections, trauma, drowning, and hypothermia), and identify the actual time of onset of central nervous system insult resulting in CP (prenatal, natal, post-natal, during the first years of life).[28,29]

The long-term duration of gross motor function improvements from HBRT and hippotherapy should be investigated beyond the 6- to 16-week recovery periods studied thus far.[2,7,8,17] Research protocols and data analyses of gross motor function during recovery should guard against being influenced by other confounding variables (e.g. changes in physical therapy or occupational therapy regimens, illnesses, medications, neurological or orthopedic surgeries, use of botulinum toxin, or introducing another sports therapy such as aquatic therapy).

Larger studies on children with CP with all levels of disability should be conducted. The Gross Motor Function Classification System (GMFCS)[30] with its five levels of gross motor classification based on differences in self-initiated movement with emphasis on sitting and walking[31] is designed for children with CP aged 12 years or younger. The GMFCS has been reported to be quick and easy to use, valid, and reliable among 48 physical therapists, occupational therapists, and developmental pediatricians, all with expertize in CP.[30] Future HBRT and hippotherapy studies using the GMFM should include sufficient numbers of children with CP for each of the five GMFCS levels. These data would be clinically useful for clinicians attempting to predict gross motor function improvement for their patients based upon GMFCS level..

Ninety percent of children with varying disabilities in North America participate in HBRT compared with only 10% of children with disabilities who participate in horseback riding programmes conducted as hippotherapy.[10,11,23] Presently, there is no peer-reviewed article published in the medical literature comparing the efficacy of HBRT and hippotherapy to improve gross motor function *in the same study*.

HBRT and hippotherapy have become very popular in North America. They are sought by parents of children with CP to complement their child's traditional physical and occupational therapy. HBRT and hippotherapy encourage children's long-term participation and enthusiasm in their own life-long rehabilitation through enjoyable sports used as therapy, defined in the medical literature as sports therapy.[2] The growing public demand for HBRT and hippotherapy has lead to the establishment of 690 horseback riding centers with NARHA membership, serving 36 000 children in North America.[32,33] The number of other independent horseback riding therapy programs not affiliated to NARHA who offer HBRT and hippotherapy in North America is presently unknown.

Before recommending HBRT or hippotherapy to parents of children with CP, clinicians should have up-to-date information about the facilities available in their locality. This should include the names and telephone numbers of the HBRT and hippotherapy centers, their proximity to their patients, costs, and type and quality of service, as well as knowledge on safety issues, such as levels of staffing and training of instructors and side-walkers.

In conclusion, research evidence suggests that clinicians and therapists can recommend either instructor-directed HBRT or therapist-directed hippotherapy as efficacious, medically-indicated therapy for gross motor rehabilitation of children with CP. Further studies with larger samples, blinded assessment, and non-riding controls are needed to conclusively evaluate and compare instructor-directed HBRT and therapist-directed hippotherapy.

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Letter to the Editor

'Transient dystonic toe-walking: differentiation from cerebral palsy and a rare explanation for some unexplained cases of idiopathic toe-walking'

SIR – Newman et al.'s interesting article on transient dystonic toe-walking[1] reminded me of a number of young toe-walking children, who appeared to exhibit lower limb flexor and extensor synergies and then lose them, rather in the manner that much mass patterning, 'overflow', and Fog patterning disappear with motor maturation. What marked them out was that when crawling, as they alternately flexed their hips, they actively flexed their knees, so that the lower leg and foot were raised well above the floor. As the hip extended, however, there was no equivalent knee hyperextension. Like most immature movements/postures, the aberrance disappeared first in the less posturally demanding activity (crawling) and then shortly afterwards in walking.

This may be a transient phenomenon or an immature sign of a mild but permanent movement disorder; but from an immediate clinical viewpoint they stopped walking on tiptoe.

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