A Comparison of the Leg Coordination Patterns of Preterm and Fullterm Infants: A Meta-Analysis

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Background and Purposes: The purposes of this meta-analysis were (1) to investigate the relation between prematurity and the parameters of infant kicking, and (2) to examine to what degree the effect size varies as a function of age, study type, publication type, and country of origin. **Methods:** Six studies met all the inclusion criteria and were used for this meta-analysis. A r-indicator was used to represent the effect size indicating the difference between low-risk preterm and full term infants and the difference in kinematic variables between high-risk preterm and full term infants. A fixed-effect model was assumed in this study. To determine whether the r-indicators were derived from a common population, a heterogeneity analysis (Q) was computed for each kinematic variable. Potential moderators (study type, publication type, country of origin, and age) were analyzed for each variable. **Results:** Overall, there was a consistent moderate to large effect size for intralimb coordination variables between high-risk preterm and full term infants. For other kicking parameters, there was a small effect size between preterm infants (both low-risk and high-risk groups) and full term infants. From the moderator analyses, studies testing high-risk infants younger than 4 months had a small positive effect for the measures of intralimb coordination, the hip-knee and hip-ankle joint correlations; whereas studies testing infants older than 4 months had a large positive effect on these hip-knee and hip-ankle pairs. On the contrary, studies testing low-risk infants younger than 4 months had a medium positive effect; whereas studies testing low-risk infants older than 4 months showed no effect. **Conclusion:** The results suggest that intralimb coordination parameters after 4 months of age may be early indicators of atypical coordination since low-risk infants resolved their differences after 4 months of age but high-risk infants sustained the atypical intralimb coordination. (FJPT 2002;27(6):303-313)

Key Words: Meta-analysis, Leg movements, Preterm, Full term, Development

Modern advanced peri- and post-natal medical techniques have successfully decreased the mortality in preterm infants.[1,2] This has led to a corresponding increase in the number of infants with developmental delay and disability.[1,2] Approximately 5-15% of infants born prematurely with a birth weight less than 1500 grams develop cerebral palsy, and 25-50% of them were reported to be clumsy later at school age.[1,2] Consequently, it is critical to identify these infants at risk at an early age, so that intervention may begin at the outset of neuromotor problems.

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Kicking is one of the earliest coordinated behaviors in infancy. Kicking patterns have been analyzed both quantitatively and qualitatively in attempts to predict neuromotor sequelae following preterm birth.[3-6] Kicking patterns change with age in healthy full term infants; whereas preterm infants with brain lesions tend to retain their kicking patterns without any further development.[3-6] It is reasonable to question if infants at-risk for developing motor problems will have different kicking coordination patterns, when compared to healthy infants.

There is limited knowledge available concerning the comparison of the characteristics of coordination patterns between preterm and full term infants. The sample size of these studies, however, were small (less than 30 infants in most of the studies), their subjects varied in age (ranged from full term to 11 months of age) at the time of testing and results were inconsistent among different studies. A meta-analysis would be able to address these problems and allows a quantitative analysis across studies regardless of differences in method. Results from different kicking studies in the literature could be combined and compared to derive a general conclusion of the relationship between prematurity and kicking coordination to overcome the differences in age at the time of testing and the low power due to small sample size. Moreover, the heterogeneity of tests and moderator analyses of the effect size from the procedure could help to identify the possible influencing factors and offer a better theoretical and practical framework for the direction of future research.

The purpose of this meta-analysis was to assess the relation between preterm birth and the development of coordinated kicking. The research questions addressed included: (1)What was the magnitude of the relation between prematurity and the parameters of infant kicking? (2) To what degree did the effect size vary as a function of infant age, study type, publication type, and country of origin?

METHOD

Potentially relevant studies were identified through a computer-assisted search of the PsycInfo, and Medline database between 1975 and 2000. The key words used in the search were "leg movements", "kicking", "infants", "kinematics", "spatiotemporal variables", "full term", "premature infants", and "preterm". The authors' names from potentially relevant studies were also entered as key words to obtain additional titles. The citation listed in the retrieved articles (citation tracking) was also obtained. In addition, conference proceedings and unpublished theses and dissertations were identified through a computer-assisted search of "dissertation index". The languages used were limited to English and Chinese. The entire search yielded 34 non-overlapping studies.[7-40]

The inclusion criteria were: (1)Outcome measures were obtained during spontaneous kicking (no external stimuli offered during infant testing). (2)Full term infants and preterm infants were compared. (3)Spatiotemporal measures of leg movements (e.g. kick rate, duration, and amplitude) and/or interlimb and intralimb coordination variables (measured by Pearson correlation coefficients or cross-correlation functions) were included as dependent variables. (4)Statistical results were reported in sufficient detail to compute or estimate effect sizes.

Twenty-five of the 34 studies did not meet the criteria for inclusion in the meta-analysis and were eliminated from the review.[7-31] Three more studies were excluded, which met the first three criteria but did not offer sufficient information to calculate effect sizes.[32-34] One of these three reported median and inter-quarter ranges[a] but did not report means and standard deviations.[32] The remaining two studies reported the maximal values of the spatiotemporal variables but not means and standard deviations.[33-34] The six studies that met the criteria are listed in Table 1.

Coding procedures

A meta-analysis code book was used to code the extracted demographic, methodological, and miscellaneous

[a] The non-parametric estimator of effect size can be computed only when all of the original raw data are available.[41]

variables from each study included in this meta-analysis. The demographic variables included age, ethnicity, and gender. Sample size, sampling method, research design, statistics, type of kinematic variables, type of stimuli, states of the infants, sampling rate during data collection, and collection time were coded as methodological characteristics. Year and type of publication (journal, book chapter, dissertation, proceeding), name of the authors, country, and affiliation of the authors were included in the miscellaneous variables. There was no quality score in this meta-analysis since most of the studies were descriptive. All the coding task was done by the first author.

Data analysis

We used the r indicator to represent the effect size indicating the difference between the preterm and full term infants for each kinematic variable. The computation of effect size estimates was based on the handbook of Cooper and Hedges.[42] The r indicator is used to describe the strength of association between the independent variable (i.e. prematurity) and the dependent variable (i.e. kinematic parameters). After computing the individual effect sizes for each study, all the effect sizes with the same kinematic parameter were combined to form a common estimate. Based on Cohen's definitions of small, medium, and large effect sizes, the r of 0.10 was considered small, the r of 0.30 was considered medium, and the r of 0.50 was considered large.[43] In this study, effect sizes were computed from the t and F (degree of freedom = 1) ratios. If the study reported means, standard deviations, and sample sizes of both preterm and full term groups, a t-value was computed and then converted to the r indicator.[42] A positive r-indicator meant that the full term group had a more mature pattern than the preterm group; whereas a negative r-indicator meant that the preterm group had a more mature pattern than the full term group. Thelen and Smith's definition of a mature kicking pattern was followed in the present study.

Separate r-indicators were calculated for full term versus preterm infants who were at low risk for neuro developmental disabilities (low-risk preterm infants) and for full term versus preterm infants who were at high risk for neurodevelopmental disabilities (high-risk preterm infants). Low-risk preterm infants were defined as preterm infants who were born at a gestational age between 32 to 36 weeks, appropriate for gestational age (AGA)[b], no severe respiratory distress, and/or no existing Grade III and IV intraventricular hemorrhage after birth.[39] High-risk infants included infants born before 32 weeks' gestational age, small for gestational age (SGA)[c], and Grade III or IV intraventricular hemorrhage after birth or with some existing developmental delays.

The r-indicator was calculated for all hypotheses and combined both unweighted and weighted by sample size. A fixed effect model was assumed in this study. To determine whether the r-indicators shared a common effect size (i.e. consistent across all hypotheses), a heterogeneity analysis (Q) was computed for all outcome variables.[42] Should the heterogeneity analysis be significant, it would suggest that not all of the effect size estimates are drawn from the same population and therefore a moderator analysis is warranted (see reference 42 for detailed introduction in heterogeneity and moderator analyses).[42] Based on previous research and the availability of data, potential moderators (study type, publication type[d], country of origin, and age) were subjected to further analysis. A contrast analysis was used to evaluate the impact of these moderators on outcome variables.

RESULTS

Characteristics of the selected studies

A total of 92 preterm and 79 full term infants were studied in these six reports. Five of the six studies included infants with both low and high-risk preterm infants (Table 1.). The corrected age at testing varied from term to 47.2 weeks of age. Forty-two percent of the preterm infants and 59 % of the full term infants were female. Three studies used

[b] AGA is a term used to describe a baby whose birthweight was within the normal range for the babies of the same gestational age.
[c] SGA is a term used to describe a baby whose birthweight was below the 10th percentile for babies of the same gestational age.
[d] Whether a study was published or unpublished was determined at the time of the literature search.

cross-sectional designs and three were longitudinal. Three studies were published in journals and three were not. All the unpublished reports were theses or dissertations. One of the 3 unpublished reports used a longitudinal design (Table 1. for details).

The r-indicators computed for 88 hypotheses for the effect sizes between low-risk preterm and full term and 58 hypotheses for the effect sizes between high-risk preterm and full term are shown in Table 2. and 3.

Overall effects and influences of moderators

Temporal variables

The mean r-indicator between low-risk preterm and full term infants for total kick duration, flexion phase, intrakick pause, extension phase and interkick pause was small (Table 2.). Tests of heterogeneity Q for the temporal variables showed significance in total kick duration and interkick pause (Table 2.). Based on the moderator analyses, none of the proposed moderators (i.e. study type, publication type, countries of origin, and age) significantly affected total kick duration; however, study type and country of origin were significant moderators for interkick pause. Studies with longitudinal designs had a small positive effect on interkick pause ($r=.12$); whereas studies with cross-sectional designs had a large negative effect on interkick pause ($r=-.55$). Studies done outside the United States had a small positive effect on interkick pause ($r=.12$); whereas studies done within the United States had a large negative effect on interkick pause ($r=-.55$).

The mean r-indicator between high-risk preterm and full term infants for total kick duration, flexion phase, intrakick pause, extension phase and interkick pause was small (Table 3.), similar to the comparison between low-risk preterm and full term infants. Tests of heterogeneity Q for the temporal variables showed significance for the flexion phase only (Table 3.). Age was a significant moderator for the flexion phase: studies testing infants older than 4 months had a medium positive effect ($r=.42$); whereas studies testing infants younger than 4 months had almost no effect ($r=-.003$).

Intralimb coordination

The mean r-indicator between low-risk preterm and

Table 1. Demographic data of the studies included in this research synthesis.

Authors	Citation	Study type	Testing age (at corrected age)	Country of origin	Sample size (preterm/fullterm)
Heriza	Phys Ther, 1988, 68:1687-93	Cross-sectional	Term age (2-3 days after birth)	U.S.A.	(10/15) low-risk preterm vs. fullterm
Geerdink et al.	Dev Psychobiol, 1996, 29:335-51	Longitudinal	6 weeks, 12 weeks, and 18 weeks	The Netherlands	(10/13) low-risk, high-risk preterm and full term
Clayton-Krasinski	Doctoral dissertation, 1993, New York University	Cross-sectional	47.2 weeks	U.S.A.	(10/10) developmental delays vs. full term
Jonsdottir	Doctoral dissertation, 1999, Boston University	Cross-sectional	5 weeks	U.S.A.	(20/10) low-risk, high-risk preterm and full term
Vaal et al.	Dev Psychobiol, 2000, 36:111-22	Longitudinal	6 weeks, 12 weeks, 18 weeks, and 26 weeks	The Netherlands	(20/9) low-risk, high-risk preterm and full term
Chen	Master thesis, 2000, National Taiwan University	Longitudinal	2 months and 4 months	Taiwan	(22/22) low-risk, high-risk preterm and full term

Table 2. The r-indicators on duration, intralimb coordation, amplitude, kick rate and interlimb coordination between low-risk preterm and full term infants

Variable	No. of tests	unweighted r	weighted r	heterogeneity Q
Duration				
Total kick duration	7	0.103	0.040	8.238†
Flexion phase	7	0.126	0.093	2.836
Intrakick pause	7	0.201	0.137	3.343
Extension phase	7	0.111	0.069	2.049
Interkick pause	6	-0.007	-0.042	9.794†
Intralimb Coordination				
Hip-Knee pair	11	0.225	0.192	42.845†
Hip-Ankle pair	11	-0.038	-0.076	8.225†
Knee-Ankle pair	11	-0.019	-0.054	15.509†
Amplitude				
Hip flexion	4	-0.030	-0.037	6.06*
Kick rate	6	-0.048	-0.030	13.615†
Interlimb Coordination				
%alternate kicking	6	0.155	0.106	3.344
%simultaneous kicking	6	-0.012	-0.028	3.052

*p<.05
†p<.01

full term infants for hip-knee correlation, hip-ankle correlation, and knee-ankle correlation was small (Table 2.). Tests of heterogeneity Q for the intralimb coordination variables showed significance in all joint pairs (Table 2.). Study type, country of origin, and age were significant moderators for hip-knee correlation. Studies with a longitudinal design had a small positive effect (r=.12); whereas studies with a cross-sectional design had a large positive effect (r=.60). Studies done outside the United States had a small positive effect (r=.12); whereas studies done within the United States had a large positive effect (r=.60). Studies testing infants younger than 4 months had a medium positive effect (r=.30); whereas studies testing infants older than 4 months had a very small effect (r=- .08). For hip-ankle correlation, study type and countries of origins were significant moderators. Studies with a longitudinal design showed almost no effect (r=.04); whereas studies with a cross-sectional design exhibited a large positive effect (r=.61). Studies done outside the United States had almost no effect (r=.04); whereas studies done within the United States had a large positive effect (r=.61). For knee-ankle correlation, none of the moderators was significant.

The mean r-indicators between high-risk preterm and full term infants for hip-knee correlation, hip-ankle correlation, and knee-ankle correlation were medium, large, and small, respectively (Table 3.). Tests of heterogeneity Q for the intralimb coordination variables showed significance in all joint pairs (Table 3.). Publication type and age were significant moderators for hip-knee correlation. Studies published in journals had a large positive effect (r=.62); whereas non-published studies had a small positive effect (r =.22). Studies testing infants younger than 4 months had a small positive effect (r=.18); whereas studies testing infants older than 4 months had a large positive effect (r=. 46). For hip-ankle correlation, study type and age were the significant moderators. Studies with longitudinal designs had a medium effect (r=.30); whereas studies with a cross-sectional designs had a large effect (r=.87). Studies testing

Table 3. The r-indicator of duration, intralimb coordination, amplitude and interlimb coordation between high-risk preterm and full term infants

Variable	No. of tests	unweighted r	weighted r	heterogeneity Q
Duration				
Total kick duration	4	0.154	0.155	0.104
Flexion phase	4	0.219	0.222	4.394*
Intrakick pause	4	0.062	0.084	0.866
Extension phase	4	0.199	0.203	0.338
Intralimb Coordination				
Hip-Knee pair	8	0.441	0.329	14.461†
Hip-Ankle pair	8	0.510	0.444	67.382†
Knee-Ankle pair	8	0.206	0.136	8.138†
Amplitude				
Hip flexion	4	-0.027	-0.054	3.249
Interlimb Coordination				
%alternate kicking	6	0.061	0.086	1.771
%simultaneous kicking	6	0.016	-0.001	5.059*

*$p<.05$
†$p<.01$

infants younger than 4 months had a small positive effect (r =.14); whereas studies testing infants older than 4 months had a large positive effect (r=.67). For knee-ankle correlation, none of the moderators was significant.

Interlimb coordination

The mean r-indicator between low-risk preterm and full term infants for the proportion of alternate kicking and the proportion of simultaneous kicking was small (Table 2.). Tests of heterogeneity Q for the interlimb coordination variables did not reach statistical significance (Table 2.).

The mean r-indicator between high-risk preterm and full term infants for the proportion of alternate kicking and the proportion of simultaneous kicking indicated almost no effect (Table 3.). Tests of heterogeneity Q for the interlimb coordination variables showed significance on the proportion of simultaneous kicking (Table 3.). However, none of the moderators was significant. That is, the effect sizes of alternate kicking and simultaneous kicking were not derived from a common population; however, the moderators suggested in this study (study type, publication type, country of origin, and age) could effectively explain the heterogeneity of the effect sizes.

Spatial variables

The most studied spatial variable was hip flexion amplitude. The mean r-indicator between low-risk preterm and full term infants for the hip flexion amplitude indicated almost no effect (Table 2.). Test of heterogeneity Q for the hip flexion amplitude showed significance (Table 2.). From the moderator analyses, age was the significant moderator for hip flexion amplitude. Studies testing infants younger than 4 months had a small negative effect (r=-.15); whereas studies testing infants older than 4 months had a small positive effect (r=.21).

The mean r-indicator between high-risk preterm and full term infants for the hip flexion amplitude indicated almost no effect (Table 3.). Test of heterogeneity Q for the hip flexion amplitude showed significance (Table 3.). However, none of the moderators was significant.

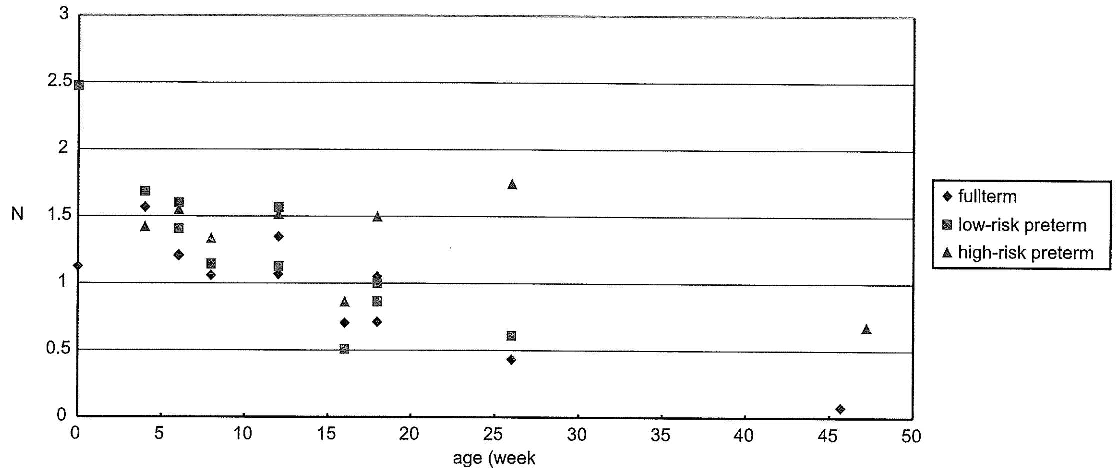

Figure 1. The correlation coefficients between hip and knee joints in full term infants (◆), low-risk preterm infants (■), and high-risk preterm infants (▲) across age 35-40. The higher the correlation coefficient, the more synchronized kicking pattern between the two joints. The correlation coefficients gradually decreased in both full term group and low-risk preterm group; whereas the correlation coefficient remained high in high-risk preterm group.

Kick rates

The mean r-indicator between low-risk preterm and full term infants for the kick rate indicated almost no effect (Table 2.). Test of heterogeneity Q for the kick rate showed significance (Table 2.). From the moderator analyses, study type, and country of origin were the significant moderators for kick rate. Studies with a longitudinal design had a small negative effect ($r=-.16$); whereas studies with a cross-sectional design had a large positive effect ($r=.49$). Studies done outside the United States had a small negative effect ($r=-.16$); whereas studies done within the United States had a large positive effect ($r=.49$).

Only one study compared the kick rate between high-risk and full term infants. Therefore, no synthesized data were reported for kick rate between these groups.

DISCUSSION

One remarkable and consistent finding was the medium to large effect sizes for intralimb coordination, especially the hip-knee correlations and the hip-ankle correlations, between high-risk preterm and healthy full term infants. Studies testing infants younger than 4 months had a small effect between high-risk preterm and full term groups for intralimb coordination, whereas studies testing infants older than 4 months had a large effect between groups. Typically healthy full term infants decreased the hip-knee synchronization with age while high-risk infants did not (Figure 1.). This stable, high correlation in high-risk preterm infants might be due to abnormal muscle tone, an immature neural system or insufficient strength or as yet unidentified factors.[5,6,32-34] Moreover, high-risk preterm infants usually combined severe medical complications, such as respiratory distress syndrome, chronic lung disease, which have been reported as risk factors to influence infants' motor development.[46] This difference in coordination suggests that the persistence of an in-phase kicking pattern, characterized with high interjoint correlations, is a potential means for the very early identification of movement disorders in high risk preterm infants. Longitudinal studies of infants through the first years of life will provide the necessary data to understand more fully the long-term consequences of this early pattern.

In contrast, the average effect sizes reflecting intralimb coordination, especially the hip-knee pair and hip-ankle pair, between low-risk preterm and healthy full term infants were very small. Studies testing infants younger than 4 months had a medium positive effect between low-risk preterm and full term groups; whereas studies testing infants older than 4 months showed no effect between these groups. Low-risk infants had a higher correlation coefficient at the early age but this reduced gradually with age (Figure 1.). Low-risk infants may adapt their strength, muscle tone, and neural systems to gradually resolve the discrepancy from the healthy full term infants.

In this article, intralimb coordination was the only one significant kinematic variable to have obvious relationship with prematurity; whereas other kinematic variables showed almost no relation. For the variables with small or no relation with prematurity, most of the variables had significant heterogeneity tests, showing the studies combined in this article were not from the same population. That is, the findings of these variables were inconsistent across studies. Further research is needed.

Study type was a common moderator. Studies with a cross-sectional design tended to have large effects between preterm and full term infants; whereas studies with a longitudinal design tended to have a small or even no effect. However, those studies with a cross-sectional design usually tested infants at a younger age and, as a result, might have been confounded with the effect of age. Longitudinal studies of preterm infants suggest that there are no significant differences between low risk preterm infants and infants born at term.[36,39,40] The results from the cross-sectional designs, which tested preterm infants once at their earlier age, could be misleading in terms of the longer-term sequelae of prematurity.

The present meta-analysis is limited by the numbers of studies available, as only six studies were included. None of the studies were coded for quality, nor did we test for the effect of other moderators such as muscle strength or infant alertness on the coordination pattern. None of the studies followed infants for a sufficiently long period of time to determine developmental outcomes.

This meta-analysis can serve as a guide for future analyses of leg coordination patterns. For future studies, a longitudinal design with more data points and larger sample sizes are needed to fully investigate the relation of prematurity and kicking characteristics. In addition, other factors which might influence coordination, such as muscle strength, infant alertness, anthropometric data, and body weight should be carefully coded to determine the most influential factors on leg coordination. A more complete understanding of early coordination problems is necessary before the most appropriate intervention programs can be designed for these very young infants.

In conclusion, early leg coordination in kicking can serve as a potentially useful indicator to therapists for early identification of coordination problems. More studies, with larger samples and longitudinal designs to provide data from birth through the first years of life, are necessary to determine the most important factors for the early coordination of leg movements.

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REFERENCES

1. Volpe JJ. Brain injury in the premature infant - Current concepts of pathogenesis and prevention. Biol Neonate 1992; 62: 231-42.
2. Ornstein M, Ohlsson A, Edmonds J. Neonatal follow-up of very low birthweight/extremely low birthweight infants to school age: a critical overview. Acta Pediatr Scand. 1991;80:741-8.
3. Fetters L, Jonsdottir J, Tronick EZ. Dynamic organization of leg movements in very low birthweight infants. [abstract] Infant Behav Dev 1998;126.
4. Heriza C. Qualitative changes in joint coordination with age in preterm infants with documented hemorrhages. [abstract] Pediatric Phy Ther 1991;3.

5. Prechtl H FR. Qualitative changes of spontaneous movements in fetus and preterm infant are a marker of neurological dysfunction. Early Hum Dev 1990;23(3):151-8.
6. Thelen E, Smith L. A Dynamic Systems Appraoch to the Development of Cognition and Action. Cambridge: MIT Press; 1994.
7. Thelen E, Fisher DM. The organization of spontaneous leg movements in newborn infants. J Motor Behav 1983;15:353-77.
8. Droit S, Boldrini A, Cioni G. Rhythmical leg movements in low-risk and brain-damaged preterm infants. Early Hum Dev 1996;44:201-13.
9. Thelen E, Bradshaw G, Ward JA. Spontaneous kicking in month-old infants: Manifestation of a human central locomotor program. Behav Neural Bio 1981;32:45-53.
10. Zhu J, Konishi Y, Fujii Y, Saito M, Sudo M. Developmental course of spontaneous kicking movements in low-risk preterm infants from 35 to 38 weeks of postmenstrual age. Dev Brain Dys 1996;9:262-7.
11. Ulrich BD, Ulrich DA. Spontaneous leg movements of infants with Down Syndrome and nondisabled infants. Child Dev 1995;66:1844-55.
12. Heriza CB. Organization of leg movements in preterm infants. Phy Ther 1988;68:1340-6.
13. Thelen E, Skala KD, Kelso JAS. The dynamic nature of early coordination: Evidence from bilateral leg movements in young infants. Dev Psych 1987;23:179-86.
14. Thelen E, Ridley-Johnson R, Fisher DM. Shifting patterns of bilateral coordination and lateral dominance in the leg movements of young infants. Dev Psychobiol 1983;16:29-46.
15. Jensen JL, Ulrich BD, Thelen E, Schneider K, Zernicke RF. Adaptive dynamics of the leg mvoement patterns of human infants: I. The effects of posture on spontaneous kicking. J Motor Behav 1994; 26:303-12.
16. Schneider K, Zernicke RF. Ulrich BD. Jensen JL. Thelen E. Understanding movement control in infants through the analysis of limb intersegmental dynamics. J Biom 1992;25:145-8.
17. Thelen E, Fisher DM. Newborn stepping: An explanation for a 'disappearing' reflex. Dev Psychol 1982;18:760-75.
18. Thelen E, Fisher DM. From spontaneous to instrumental behavior: Kinematic analysis of movement changes during very early learning. Child Dev 1983; 54:129-40.
19. Thelen E. Three-month-old infants can learn task-specific patterns of interlimb coordination. Psychol Science 1994;5:280-5.
20. Thelen E. Developmental origins of motor coordination: Leg movements in human infants. Dev Psychobiol 1985;18:1-22.
21. Thelen E. Rhythmical stereotypies in normal human infants. Ani Behav 1979;27:699-715.
22. Hayes MJ, Plante L, Kumar SP, Delivoria-Papadopoulos M. Spontaneous motility in premature infants: Features of behavioral activity and rhythmic organization. Dev Psychobiol 1993;26:279-91.
23. Robertson SS. Infants of diabetic mothers: Late normalization of fetal cyclic motility persists after birth. Dev Psychobiol 1988;21:477-90.
24. Robertson SS. Human cyclic motility: fetal-newborn continuities and newborn state differences. Dev Psychobiol 1987;20: 425-42.
25. Piek JP. A quantitative analysis of spontaneous kicking in 2-month-old infants. Hum Mov Sci 1996;15:707-26.
26. Piek JP. Gasson, N. Spontaneous kicking in fullterm and preterm infants: Are there leg asymmetries? Hum Mov Sci 1999;18: 377-95.
27. Angulo-Kinzler RM. Exploration and control of leg movements in infants. Indiana: Indiana University. Doctoral dissertation: 1997.
28. Collier DH. Goal-directed movement in infants with Down Syndrome. Indiana: Indiana University. Doctoral dissertation: 1993.
29. Vaal J, van Soest AJK, Hopkins B. Sponaneous kicking behaviors in infants: Age-related effects of unilateral weighting. Dev Psychobiol 2000;36:111-22.
30. Clark-Touesnard ME. Infant leg movement patterns: The effect of weighting. New Brunswick: The University of New Brunswick, Master thesis:1994.
31. Heriza CB. Qualitative changes in joint coordination with age in preterm infants with documented hemorrhages. Proceedings of Combined Section Conference, American Physical Therapy Association, Feb. 5-10, 1992, San Francisco, CA.
32. Van der Heide JC, Paolicelli PB, Boldrini A, Cioni G. Kinematic and qualitative analysis of lower-extremity movements in preterm infants with brain lesions. Phy Ther, 1999;79:546-57.
33. Piek JP, Carman R. Developmental profiles of spontaneous movements in infants. Early Hum Dev 1994;109-26.
34. Piek JP, Gasson N. Spontaneous kicking in fullterm and preterm infants: Intralimb and interlimb coordination. Australian Educ Dev Psychol 1997;14:23-34.
35. Heriza CB. Comparison of leg movements in preterm infants at term with healthy full-term infants. Phy Ther 1988;68:1687-93.
36. Geerdink JJ, Hopkins B, Beek WJ, Heriza CB. The organization of leg movements in preterm and full-term infants after term age. Dev Psychobiol 1996;29:335-51.
37. Clayton-Krasinski D. Kinematic analysis of spontaneous kicking and infant stepping in developmentally delayed infants compared with healthy infants, New York: New York University, Doctoral dissertation; 1993.
38. Jonsdottir J. Characteristics of spontaneous leg movements in very low birth weight infants with and without neonatal white

matter disorders and full term infants at one month of age. Boston: Boston University. Doctoral dissertation; 1999.
39. Vaal J, van Soest AJ, Hopkins B, Sie LTL, Knaap MS. Development of spontaneous leg movements in infants with and without periventricular leukomalacia. Exp Brain Res 2000.
40. Chen LC. Comparison of early motor development between very low birthweight infants and normal full-term infants. Taipei: National Taiwan University. Master thesis; 1999.
41. Hedges LV, Olkin I. Statistical Methods for Meta-Analysis. San Diego: Academic Press; 1985.
42. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd edition. Hillsdale: Erlbaum; 1988.
43. Cooper H, Hedges LV. The Handbook of Research Synthesis. New York: Russell Sage Foundation; 1994.
44. Chen Y-P, Fetters L, Holt KG, Saltzman E. Making the mobile move: Constraints from task and environment. Infant Behav Dev, in press.
45. Campbell SK, Palisano RJ, Vander Linden DW. Physical Therapy for Children. Philadelphia: W.B. Saunders Co.; 2001.
46. Landry SH, Fletcher JM, Denson SE, Chapieski ML. Longitudinal outcome for low birth weight infants: effects of intraventricular hemorrhage and bronchopulmonary dysplasia. J Clin Exp Neuropsychol 1993; 15(2):205-18.

早產兒與足月產嬰兒踢腳動作之整合研究

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背景與目的：本研究的目的為(1)研究早產與嬰兒踢腳動作之相關程度，(2)檢驗測試年齡、研究類型、發表與否、以及研究國度與踢腳動作有效尺度(effect size)的關聯。**方法**：總共找到了34篇文章，其中只有6篇符合收案條件用作分析。利用r指標來分別代表在各項動力學因子中低危險群早產兒與足月產嬰兒間，以及高危險群嬰兒與足月產嬰兒間的有效尺度。**結果**：整體而言，早產與嬰兒踢腳動作只有弱相關之相關程度，唯一例外的是在高危險群早產兒與足月產嬰兒間的肢體內協調度(intralimb coordination)有中度至高度相關。進一步分析顯示，在比較高危險群早產兒與足月產嬰兒間的協調度時，若是受測嬰兒年齡小於4個月大時，僅為小的有效尺度；但若是大於4個月時，則為大的有效尺度。相反的，在比較低危險群早產兒與足月產嬰兒時，若是年齡小於4個月時，為中度的有效尺度；但若是大於4個月時，有效尺度則幾乎為0。**結論**：經由本整合研究的發現，建議可利用四個月大之後的肢體內關節協調度來區分哪些嬰兒為日後有發展遲緩的高危險群。(物理治療 2002；27(6)：303-313)

關鍵詞：整合研究、腳部動作、早產兒、足月兒、發展

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