We examined the relationship between postural control and fine motor skills of preterm infants at 6 and 12 months adjusted age. The Alberta Infant Motor Scale was used to measure postural control, and the Peabody Developmental Motor Scales II was used to measure fine motor skills. The data analyzed were taken from 105 medical records from a preterm infant follow-up clinic at an urban academic medical center in south Taiwan. Using multiple regression analyses, we found that the development of postural control is related to the development of fine motor skills, especially in the group of preterm infants with delayed postural control. This finding supports the theoretical assumption of proximal–distal development used by many occupational therapists to guide intervention. Further research is suggested to corroborate findings.


Advances in medical technology have contributed to a significant increase in the survival rates of preterm infants, who are at high risk for long-term neurological, cognitive, and behavioral complications (Aylward, 2005). Among these high-risk areas, motor development is reported to be more affected by premature birth than are other developmental domains (Lorenz, Wooliever, Jetton, & Paneth, 1998) and is therefore an important area to monitor in preterm infants.

The relation between postural control and fine motor skills is the primary focus of therapy when clinicians are working on young children’s motor acquisition. Clinicians often base their therapeutic interventions on the proximal–distal principle of normal motor development (Case-Smith, Fisher, & Bauer, 1989; Rosenblum & Josman, 2003). This principle suggests that motor development initially occurs proximally (i.e., in the head and trunk) and thereafter progresses outwardly toward the distal parts of the body (i.e., the hands and feet; Case-Smith et al., 1989; Loria, 1980; Skinner, 1979). *Postural control*, the ability to maintain the center body mass or a body part over a stable or moving base of support (Masion, 1998; Shumway-Cook & Woollacott, 1995), is an example of a proximal motor function. Despite widespread acceptance of the proximal–distal principle, the evidence supporting this assumption is limited (Case-Smith et al., 1989).

Both clinical and laboratory studies have examined the relationship between proximal motor function (e.g., postural control) and distal motor function (e.g., fine motor skills) in the typically developing population at different age ranges (Case-Smith et al., 1989; Fallang, Saugstad, & Hadders-Algra, 2000; Rochat, 1992; Rosenblum & Josman, 2003; Thelen & Spencer, 1998). These studies collectively do not lend strong support for the proximal–distal principle,
The first purpose of our study was to examine the general relationship between postural control and fine motor skills in preterm infants at 6 and 12 mo adjusted age. In addition, we examined the relationship between postural control and fine motor skills, comparing groups with different adjusted ages and groups with and without motor delays separately.

**Method**

**Research Design**

We used a cross-sectional design (Portney & Watkins, 2009) to investigate the differences in postural control and fine motor skills between preterm and full-term infants at the adjusted ages of 6 and 12 mo. The institutional review board of the National Cheng Kung University Hospital and New York University Human Subjects Review Board reviewed and approved the study procedures.

**Participants**

National Cheng Kung University Hospital in Taiwan provided data from infants’ 6- and 12-mo preemie follow-up visits between August 2008 and April 2009. All the medical records reviewed met the following criteria: (1) the preterm infant’s birth weight was ≤1,500 g; (2) the infant’s gestational age was <37 wk; (3) the infant had no marked neurological impairments, such as Grade III or IV intraventricular hemorrhage or periventricular leukomalacia; and (4) the infant had no congenital impairment.

Tien-Ni Wang reviewed 133 medical records from the preemie follow-up program recorded at National Cheng Kung University Hospital in Taiwan. The preemie follow-up team evaluated 71 boys and 62 girls between August 2008 and April 2009. On the basis of the inclusion criteria, 12 preterm infants (8 boys and 4 girls) who had intraventricular hemorrhage, Grade III and IV, or periventricular leukomalacia were excluded. Because the data collection period spanned longer than 6 mo, 16 preterm infants (9 boys and 7 girls) were tested at both 6 and 12 mo adjusted age. One of the two sets of data collected on these 16 preterm infants was eliminated to be consistent with a cross-sectional design. Moreover, one set of data collected at 6 mo adjusted age was eliminated to balance the sample sizes for the two age groups. The final sample consisted of 105 participants: 54 preterm infants at 6 mo adjusted age and 51 preterm infants at 12 mo adjusted age.

**Instruments**

We used two standardized assessments. Postural control was measured with the Alberta Infant Motor Scale (AIMS; however. Fallang and colleagues (2000) found a strong association between the kinematics of reaching activities as an indication of fine motor skills and postural control in a laboratory setting using healthy infants ages 4 and 6 mo. Yet, in another sample of healthy infants ages 2–6 mo, Case-Smith et al. (1989) found a moderately low, albeit statistically significant, correlation between postural control and fine motor skills ($rs = .31–.35, ps < .05$) in a clinical setting. In still another study of older children, Rosenblum and Josman (2003) investigated the relationship between postural control and fine motor skills in 47 typically developing children at ages 5–6 yr and found low to moderate, but statistically significant, correlations between postural control and fine manual dexterity ($rs = -.31$ to $-.47, ps < .05$). The findings of these studies have low correlations that provide limited information about the relationship between postural control and fine motor skills.

The relationship between postural control and fine motor skills also has been investigated in the preterm infant population (de Groot, 2000; Fallang, Saugstad, & Hadders-Algra, 2003; Plantinga, Perdock, & de Groot, 1997; Samsom & de Groot, 2000); in these studies, however, only a single component of postural control was investigated. Past studies of postural control in premature infants (de Vries & de Groot, 2002; Fallang et al., 2003; Plantinga et al., 1997) examined only specific positions in the realm of possible postural control positions. For example, when studying the relationship between postural control and fine motor skills, Plantinga et al. (1997) examined only the sitting position, de Vries and de Groot (2002) examined only trunk rotation, and Fallang et al. (2003) focused only on reaching in the supine position. Because these researchers measured postural control differently, using different dimensions of postural control as indicators, drawing comparisons across studies and arriving at a conclusion about the relationship between postural control, in general, and fine motor skills is difficult.

In addition, previous studies of the relationship between postural control and fine motor skills have been limited in terms of the variety of preterm populations studied (Plantinga et al., 1997; Samsom & de Groot, 2000). The results of these studies cannot be generalized to other preterm infant populations. Samsom and de Groot (2000), for example, investigated the relationship between postural control and fine motor skills in high-risk preterm infants. They defined high-risk infants as those <32 wk gestational age, birth weight <1,500 g, and with at least one medical complication. They did not include healthy preterm infants without medical complications or preterm infants between 33 and 36 wk gestational age.
Piper & Darrah, 1994), and fine motor skills were measured by the Fine Motor scale of the Peabody Developmental Motor Scales, 2nd edition (PDMS–2; Folio & Fewell, 2000). The PDMS–2 measures included the Composite Fine Motor score and the scores of two subscales: Grasping and Visual–Motor Integration.

**Alberta Infant Motor Scale.** In this study, we used the AIMS (Piper & Darrah, 1994), a standardized norm-referenced observation- and performance-based test, to measure postural control. The AIMS evaluates the spontaneous movement repertoires of infants from birth through independent walking. It consists of 58 items assessing all components of postural control, including antigravity movements, body alignment, trunk rotation, and weight shifting in different positions (i.e., supine, prone, sitting, standing). The total raw score (sum of the positional item scores) ranges from 0 to 58. The higher the score is, the better the infant’s postural control.

Interrater reliability of the AIMS is reported to be higher than .96, and test–retest reliability ranges from .86 to .99 at different ages (Liao & Campbell, 2004). Good to excellent concurrent validity was found with other standardized motor evaluations, including the PDMS–2 and the Bayley Scales of Infant Development I and II ($r = .74–.89$; Almeida, Dutra, Mello, Reis, & Martins, 2008; Piper & Darrah, 1994). The AIMS also demonstrated good intrarater and interrater reliabilities (intra-class correlation coefficients [ICCs] = .97–.99) as well as excellent concurrent validity with the Bayley Scales of Infant Development II (.78 at 6 mo and .90 at 12 mo) when used in the Taiwanese preterm population (Jeng, Yau, Chen, & Hsiao, 2000).

**Peabody Developmental Motor Scales–2.** The PDMS–2 is a standardized and norm-referenced test that consists of a Gross Motor and a Fine Motor scale, each of which is divided into skill categories. In this study, we used the Fine Motor scale to measure fine motor skills. The Fine Motor scale consists of test items measuring (1) controlled use of the fingers and hands under the general heading of Grasping (PDMS–G) and (2) Visual–Motor Integration (PDMS–V) using test items such as reaching for and grasping an object, building with blocks, and copying designs. Test items reflect typical motor tasks for each age, including drawing and manual dexterity activities.

The test manual reported good reliability and validity, as have other studies (Folio & Fewell, 2000; Provost et al., 2004). Test–retest reliability values for the total motor quotient for a group of infants between ages 2 and 17 mo were $89–96$, those for PDMS–G for a group of infants between ages 2 and 17 mo were $82–91$, and those for PDMS–V for a group of infants between ages 2 and 17 mo were $.90–.95$. The interrater reliability ($r = .98$) and test–retest reliability (ICCs = .97) of the PDMS–2 are both high (Folio & Fewell, 2000). The concurrent validities of the Fine Motor Skill subscale of the Bayley Scales of Infant Development II (Bayley, 1969) and PDMS–2 in infants at 12 mo were reported to be between .78 and .90 (Provost et al., 2004). In this study, we used the standard score of the PDMS–2 with a mean ($M$) = 10 and a standard deviation ($SD$) = 3 to represent the performance of preterm infants’ fine motor skills.

**Procedures**

Infants with birth weight ≤1,500 g from six different hospitals in the southern region of Taiwan are automatically enrolled in the centralized preterm follow-up program at National Cheng Kung University Hospital. A follow-up team evaluates all premature infants at the adjusted ages of 6 and 12 mo with a series of neurological, cognitive, and motor development tests. The evaluation team administers the AIMS and PDMS–2 as part of the motor tests. Tien-Ni Wang, who was not a member of the evaluation team, retrieved the infants’ demographic information, birth history, and results from the motor skills assessments from the existing medical records of the follow-up clinics. All members of the evaluation team were blind to the purpose of this study.

**Data Analysis**

We analyzed the data using SPSS-PC for Windows Release 17.0 (SPSS Inc., Chicago). Initially, we used descriptive statistics to examine the tenability of the underlying assumptions of the tests of inference used to answer the questions addressed. The underlying assumptions for these tests, including linearity, normality, and homoscedasticity, were found to be tenable. Accordingly, we conducted three regression analyses, one on each of the three Fine Motor subscales of the PDMS–2 as dependent measures variables: the PDMS–G, the PDMS–V, and the Composite Fine Motor score (PDMS–F). Finally, we investigated the relationship between postural control and fine motor skills for two groups of preterm infants, those with and without motor delays at 6 and 12 mo adjusted age. In this study, we identified preterm infants as being delayed in postural control if their AIMS score was lower than the fifth percentile ranking of the norm in their respective age group (Campos et al., 2006; Piper & Darrah, 1994).
Results

Demographic Characteristics

The final sample consisted of 105 preterm infants (54 boys, 51 girls). A total of 54 infants were at 6 mo adjusted age, and 51 were at 12 mo adjusted age. Birth weight of the 105 participants ranged from 720 g to 1,496 g ($M = 1,178.50, SD = 215.47$), and gestational age ranged from 24 wk to 36 wk ($M = 29.67, SD = 2.57$). We found no significant group differences between the 6- and 12-mo adjusted age groups in terms of birth weight ($t = -0.376, df = 103, p = .708$), gestational age ($t = 1.163, df = 103, p = .247$), or gender ($x^2 = 1.591, df = 2, N = 105, p = .244$).

Postural Control and Fine Motor Skills in Preterm Infants

To make scores comparable between different ages and tests, we transformed all AIMS and PDMS–2 raw scores into standard scores. We used the standard scores printed in the AIMS test manual, which are $z$ scores ($M = 0, SD = 1$) and contingent on age (Piper & Darrah, 1994). The $z$ scores are based on a normative group of full-term infants, which explains why the $M$ for the AIMS has a negative value for this preterm population ($M = -0.56, SD = 1.08$). Fine motor skills included the PDMS–G, PDMS–V, and PDMS–F standard scores with $M = 10$ and $SD = 3$. As with the AIMS, the standard scores of the PDMS–G and PDMS–V are obtained from the PDMS–2 test manual and are contingent on age (Folio & Fewell, 2000). The PDMS–F standard score is a summary value of the PDMS–G and PDMS–V standard scores. These standard scores are based on a normative group of full-term infants, which again explains why the means for the PDMS–G ($M = 9.44, SD = 1.47$) and PDMS–V ($M = 9.74, SD = 0.89$) are all less than the full-term mean of 10.

Table 1 presents the matrix of correlations between all pairs of variables, including demographic variables (i.e., birth weight, gestational age, and gender), postural control as measured by the AIMS, and fine motor skills as measured by the PDMS–G, PDMS–V, and PDMS–F. On the basis of the correlational analyses, we found statistically significant associations between the fine motor skills variables and postural control ($r_s = .355–.440, p < .05$) when the effect of age was controlled. These results indicate that fine motor skills in terms of grasping, visual–motor integration, and composite scores of fine motor skills are associated with postural control.

### Table 1. Correlation Matrix Between All Pairs of Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. BW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. GA</td>
<td>.578**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Gender</td>
<td>.155</td>
<td>-.067</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. AIMS</td>
<td>.058</td>
<td>-.088</td>
<td>-.166</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. PDMS–G</td>
<td>.265**</td>
<td>.146</td>
<td>-.048</td>
<td>.431**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. PDMS–V</td>
<td>.200*</td>
<td>.139</td>
<td>-.089</td>
<td>.355**</td>
<td>.653**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. PDMS–F</td>
<td>.265**</td>
<td>.157</td>
<td>-.069</td>
<td>.440**</td>
<td>.950**</td>
<td>.856**</td>
<td></td>
</tr>
</tbody>
</table>


Relationship Between Postural Control and Fine Motor Skills After Controlling for Demographic Variables

Because birth weight, gender, gestational age, and adjusted age are known to correlate with fine motor skills, we examined the relationship between postural control and fine motor skills after controlling for these demographics. In this way, we could examine the unique contribution of postural control on fine motor skills over and above these demographic variables. The particular set of dependent variables included the PDMS–G, the PDMS–V, and the PDMS–F, and the particular set of independent variables included postural control (as measured by the AIMS) and the demographic control variables gender, gestational age, birth weight, and adjusted age.

The findings showed that after accounting for the effects of the control variables, postural control contributes to fine motor skills as measured by the PDMS–F, PDMS–G, and PDMS–V (Table 2). The $R^2$ values in the final model of equations indicate that after controlling for gender, birth weight, gestational age, and adjusted age, postural control uniquely explained 25.6% of the variance in fine motor skills, 24.8% of the variance in grasping fine motor skills, and 16.7% of the variance in visual–motor integration skills.

### Table 2. Multiple Linear Regression Analyses Testing the Effects of Postural Control on Fine Motor Skills in Preterm Infants

<table>
<thead>
<tr>
<th>Control Variable</th>
<th>Predictor</th>
<th>Equation</th>
<th>Intercept</th>
<th>GA</th>
<th>BW</th>
<th>Gender</th>
<th>AIMS</th>
<th>F(4, 104)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PDMS–F</td>
<td></td>
<td>15.414</td>
<td>.066</td>
<td>.002</td>
<td>-.097</td>
<td>.867**</td>
<td>8.606**</td>
<td>.256**</td>
<td></td>
</tr>
<tr>
<td>2. PDMS–G</td>
<td></td>
<td>7.633</td>
<td>.036</td>
<td>.001</td>
<td>-.015</td>
<td>.580**</td>
<td>8.223**</td>
<td>.248**</td>
<td></td>
</tr>
<tr>
<td>3. PDMS–V</td>
<td></td>
<td>8.381</td>
<td>.030</td>
<td>.001</td>
<td>-.082</td>
<td>.287**</td>
<td>5.007**</td>
<td>.167**</td>
<td></td>
</tr>
</tbody>
</table>

Relationship Between Postural Control and Fine Motor Skills in Different Age and Motor Subgroups

We further examined the relationship between postural control and fine motor skills at two different adjusted ages: 6 mo \( (n = 54) \) and 12 mo \( (n = 51) \); we also looked at the relationship for those with delayed postural control \( (n = 12) \) and those without delayed postural control \( (n = 93) \). With respect to the demographics, we found no significant differences in birth weight \( (p > .05) \) and gestational age \( (p > .05) \) between the groups of infants with and without delayed postural control or between the groups of infants at 6 and 12 mo adjusted age (see Table 3).

Table 3 shows the correlation between postural control as measured by the AIMS and fine motor skills as measured by the PDMS–F in the different subgroups defined by adjusted age and status of postural control. Although the relationship between postural control and fine motor skills is stronger in preterm infants at 6 mo adjusted age than in those at 12 mo adjusted age, the difference in the correlations is not large (.503 vs. .415). When examining the correlation between postural control and fine motor skills in the groups with and without delayed postural control, we found that infants without delayed postural control did not have a significant association between postural control (AIMS) and fine motor skills (PDMS–F; \( r = .139, p = .185 \)), whereas those with delayed postural control did \( (r = .671, p = .017) \).

Discussion

The findings of this study support postural control’s association with fine motor skills in preterm infants. The relationships between postural control and all fine motor skills variables were low to moderately significantly positive \( (r = .355–.440, p < .05) \). Analyses demonstrated that preterm infants at 6 mo adjusted age \( (r = .503) \) tend to have a stronger association between postural control and fine motor skills than those at 12 mo adjusted age \( (r = .415) \). Moreover, we found a strong, significant relationship between postural control and fine motor skills in preterm infants with delayed postural control \( (r = .671, p = .017) \), but not in those without delayed postural control \( (r = .139, p = .185) \).

The results of this study demonstrated a significant association between postural control and fine motor skills. In this study, a higher percentage of variance in the fine motor scores was explained by the scores of postural control (16.7%–25.6%) than was explained in Case-Smith et al.’s (1989) study (12%), which was based on the typically developing population. These different findings are likely the result of the different populations studied. This study’s results indicate that postural control and fine motor skills are more strongly associated in preterm infants than in typically developing infants.

When examining preterm infants in different age groups, the study results indicated that descriptively speaking, preterm infants at 6 mo adjusted age have a stronger association between postural control and fine motor skills \( (r = .503) \) than those at 12 mo adjusted age \( (r = .415) \). Van der Fits, Otten, Klip, Van Eykern, and Hadders-Algra (1999) offered an explanation of why the relationship between postural control and fine motor skills decreases with age. Van der Fits and his coauthors investigated the developmental changes in postural control accompanying reaching movements in healthy infants from 6 to 18 mo old. Their findings indicated that once an infant is successful in reaching, postural control and reaching develop relatively independently.

A unique aspect of this study was our examination of postural control as a whole. The results of this study expand the findings of previous studies that focused on only a single component or position (de Vries & de Groot, 2002; Fallang et al., 2003; Plantinga et al., 1997). These findings provide further evidence to support the relationship between general postural control and fine motor skills, including all of its components in different positions. This result is especially important for infant populations, because they develop their fine motor skills in different positions using various postural components.

Moreover, we included a wider population of preterm infants than did prior studies. This study’s population was preterm infants born between 32 and 36 wk gestational age and free of medical complications. During the past 2 decades, the number of preterm infants with younger gestational age and lower birth weight has increased dramatically; the results add to our theoretical knowledge.

Table 3. Birth Weight, Gestational Age, and Relationship Between Postural Control and Fine Motor Skills in Preterm Infants in Different Subgroups

<table>
<thead>
<tr>
<th>Group</th>
<th>Birth Weight Mean (SD)</th>
<th>Gestational Age Mean (SD)</th>
<th>Pearson r</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants with DPC</td>
<td>1,197.6 (210.0)</td>
<td>30.4 (3.3)</td>
<td>.671*</td>
<td>12</td>
</tr>
<tr>
<td>Infants without DPC</td>
<td>1,176.0 (217.1)</td>
<td>29.6 (2.5)</td>
<td>.139</td>
<td>93</td>
</tr>
<tr>
<td>6 mo AA</td>
<td>1,202.2 (210.8)</td>
<td>29.6 (2.2)</td>
<td>.503**</td>
<td>54</td>
</tr>
<tr>
<td>12 mo AA</td>
<td>1,153.4 (219.6)</td>
<td>29.8 (2.9)</td>
<td>.415**</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>1,178.5 (215.5)</td>
<td>29.7 (2.6)</td>
<td>.440**</td>
<td>105</td>
</tr>
</tbody>
</table>

Note. Postural control was measured by the Alberta Infant Motor Scale, and fine motor skills were measured by the composite fine motor score of the Peabody Developmental Motor Scale–2. AA = adjusted age; DPC = delayed postural control; M = mean; SD = standard deviation.
* \( p = .05 \). ** \( p = .01 \).
of the general relationship between postural control and fine motor skills in this population.

Clinical Implications

Infants’ motor development is a major area of focus for therapists working with children who have developmental disabilities. To fulfill the need for practical applications, we further analyzed the relationship between postural control and fine motor skills. We compared the differences between two groups: (1) a group of preterm infants without delayed postural control and (2) a group of preterm infants with delayed postural control. The results indicated that the relationship between postural control and fine motor skills is strong and significant for preterm infants with delayed postural control ($r = .671, p = .017$), although it is not significant for preterm infants without delayed postural control. These findings further echoed Van der Fits and colleagues’ (1999) conclusion that postural control and fine motor skills are two interdependent systems when the motor system is not mature or is delayed.

On the basis of our findings, we argue that the proximal–distal principle might be appropriately applied to infants with motor delay. These results, however, are different from Case-Smith’s (1989) study, in which she found a low but significant distal–proximal relationship in typically developing infants. Case-Smith suggested that the proximal–distal principle may not be a valid postulate on which to design treatment programs for infants. The different population could also explain this conflict with our own findings.

The results of this study should help therapists understand the general relationship between postural control and fine motor skills in preterm infants. We demonstrated a strong relationship between postural control and fine motor skills in preterm infants with motor delay. We also found a stronger relationship between postural control and fine motor skills in younger preterm infants at 6 mo adjusted age than at 12 mo adjusted age. This finding suggests that clinicians should consider postural control and fine motor skills as two interdependent systems when treating infants at a younger age or infants with motor delay. In addition, we propose that therapists should treat infants’ difficulties in postural control and fine motor skills concurrently until they have mastered postural control.

Limitations and Further Studies

This cross-sectional study focused on preterm infants age 1 yr or younger. Because delays in motor skills consistently appear at a later age (Churcher et al., 1993; Darlow, Horwood, Mogridge, & Clemett, 1997; Sullivan & Msall, 2007), the performance of postural control and fine motor skills and the relationship between them is worth investigating in a wider age range. Moreover, investigating the developmental motor trajectory of preterm infants using a longitudinal design is needed to verify our findings. Retrospective data collection also has some inherent limitations, such as data integrity and the issue of quality. For example, in our study, we did not establish interrater reliability between two occupational therapists on the team before administering AIMS and PDMS–2.

Conclusion

We investigated the relationship between postural control and fine motor skills in preterm infants at 6 and 12 mo adjusted age. We found that the development of postural control is related to the development of fine motor skills, especially in the group of preterm infants with delayed postural control. Understanding that the relationship between postural control and fine motor skills in infants with delayed postural control is strong might offer insight into helpful intervention strategies for preterm infants.

Acknowledgments

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