An Analysis of the Relationship Between Proximal and Distal Motor Control

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Key Words: gross and fine motor evaluation • human development • infant • posture • theory

The purpose of this investigation was to test the ontogenetic principle that the development of proximal postural stability precedes, and is necessary for, the development of distal fine motor control. The Posture and Fine Motor Assessment of Infants (Case-Smith, 1987) was used to examine the relationship between proximal and distal motor function in 60 normal infants. Low positive partial correlations were found between components of posture and fine motor control. Although all partial correlations, except those between the head component of postural control and the fine motor scores, were significant, they were not strong enough to support the validity of the proximal-distal principle. They appear instead to reflect a functional rather than an ontogenetic relationship. These findings have implications for treatment and further research.

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This article was accepted for publication February 14, 1989

The widely accepted proximal-distal principle of normal motor development was formulated in the 1920s and 1930s. According to this principle, the development of trunk stability and central axis control is a prerequisite to upper extremity function and hand usage. Proximal stability is hypothesized to allow for the independent use of the arms and hands in manipulative and purposeful activity. That is, motor development is believed to progress from gross movements to fine movements and from proximal control to distal control (Tudor, 1981).

This ontogenetic principle, which was generated in support of the concept that behavior is refined from the whole rather than built from its parts, is based on studies of embryology (Irwin, 1933) and ontogeny (Gesell, 1925). Observations of motor development in normal children suggest that children first gain control over the shoulder, waving the arm in gross, whole arm movements, and then learn to coordinate fine movements of the elbow, wrist, and fingers (Skinner, 1979). The development ofprehension also has been observed to progress in a proximal to distal direction, from palmar to fingertip control (Gilfoyle, Grady, & Moore, 1981; Tudor, 1981). Finally, children develop a range of grasping patterns that generally progress from a primitive gross, or palmar, grasp to a refined digital pinch (Illingworth, 1975).

The proximal-distal principle has been adopted by occupational and physical therapists as both a postulate of theories of normal motor development (Ayres, 1954/1974; Gilfoyle, et al., 1981) and a principle of treatment (Ayres, 1954/1974; Bobath, 1971; Bobath & Bobath, 1972; Farber, 1982; Stockmeyer, 1967; Voss, 1972). On the basis of the belief that the development or recovery of arm and hand function in persons with sustained central nervous system damage adheres to the proximal-distal principle of ontogeny, therapists often focus treatment on the development of proximal (axial) stability and control as necessary preparation for distal control or fine motor skill (Bobath, 1964; Stockmeyer, 1967; Twitchell, 1951; Voss, Ionta, & Myers, 1985). The specific treatment techniques used vary, depending on the therapist's frame of reference.

For example, therapists who design treatment programs based on the principles of neurodevelopmental treatment use proximal points of control to give the child an optimal amount of support or stability to promote isolated distal control (Bobath & Bobath, 1972). Through handling of the trunk, the therapist facilitates movement of the extremities. As the child's proximal control improves, less support and guidance are needed, and handling moves from proximal to distal aspects of the body (Scherzer & Tscharnuter, 1982). For example, as the child becomes more...
posturally stable, the therapist may guide movements at the wrist rather than at the shoulder.

In contrast, therapists who develop treatment programs based on Rood's sensorimotor treatment approach follow a proximal-to-distal motor sequence such that tonic postural stability, or cocontraction, is facilitated before distal control and skill are facilitated (Stockmeyer, 1967, 1972). A guiding treatment postulate of the Rood approach is that normal development proceeds from stability in weight-bearing patterns to mobility in non-weight-bearing patterns. Mobility built on stability is postulated to be the highest level of motor development. Skilled distal movement that includes free, coordinated, and varied patterns is superimposed on stabilized proximal body parts.

Despite its widespread acceptance, empirical evidence does not support the proximal-distal principle. Studies of proximal-distal relationships can be divided into two categories: (a) laboratory research with monkeys by neurophysiologists and (b) clinical research with children by occupational and physical therapists.

Kuypers (1963) and Lawrence and Kuypers (1965, 1968) examined the motor function of monkeys after making lesions in selected descending pathways and found that the interruption of lateral and ventromedial pathways produced contrasting disturbances in motility. More specifically, interruption of the lateral corticospinal tracts impaired the independent distal extremity and individual finger movements. In contrast, lesions in the ventromedial brain-stem pathways resulted in impaired control of axial and proximal movements. The investigators concluded that there are separate motor control systems for proximal and distal motor functions. The ventromedial brain-stem pathways maintain erect posture, neck and trunk stability, and proximal limb movement, whereas the lateral corticospinal pathways seem to control the capacity for the independent use of the hand.

In subsequent studies of monkeys, it was demonstrated that these proximal and distal motor functions develop in a predictable developmental sequence. The proximal motor system of the arm, organized mainly at the brain stem level, generally matures ahead of the cortically organized distal motor system of the hand (Lawrence & Hopkins, 1972).

Although these neurophysiological studies of the relationship between proximal and distal motor control in monkeys suggest that development is in a proximal-distal direction, they also indicate that lesions can result in a differential loss of proximal or distal motor control. Thus, these studies fail to support, and may even refute, the postulate that the development of distal control depends on the development of proximal stability.

Two clinical studies have been implemented to clarify the relationship between proximal and distal motor function. Loria (1980) examined the correlation between the degree of control in proximal and distal arm movements in 30-week-old infants. Low correlations that were not significant \((r = .37, p > .05)\) supported the theory that proximal and distal motor control develop through separate mechanisms. Caution must be observed, however, in the generalization of these results. The use of a small \((n = 12)\), homogeneous sample might have contributed to the low, nonsignificant correlations.

In the second study, Wilson and Trombly (1984) examined the relationship between proximal and distal motor function in 8 normal children and 8 children with sensory integrative dysfunction. Proximal control was measured by means of electromyographic recordings of upper extremity stabilizing muscles during weight bearing. Distal control was evaluated with the Motor Accuracy Test—Revised (Ayres, 1980) and a fine motor subset of the Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978). Although the inclusion of both normal children and children with sensory integrative dysfunction maximized the total group variability and the resultant probability of finding a significant relationship, no relationship was found between the degree of skill in activities requiring distal control and measures of proximal muscle output \((r < .20, p > .05)\). Wilson and Trombly asserted that the lack of association found between distal control and the degree of proximal muscle activity challenges the theory that proximal stability is necessary for distal control.

The lack of significant relationships in both of these studies suggests that proximal development is not necessarily a prerequisite for distal motor development. According to Ayres (1954/1974),

There is no proof that ontogeny presents the pattern on which to base this phase of rehabilitation. At this point we have only logic and empiricism to guide us. [...] a therapist cannot work very long toward the development of hand function without realizing that there is much more to the process of grasping than a functional hand. A hand capable of grasping is of little use without a strong and coordinated wrist and arm to place the hand in the proper position. The forearm, in turn, is dependent upon the humerus to position it. Similarly, the humerus is quite dependent upon the shoulder girdle for its support and direction. Without a stable trunk, the arm-hand unit cannot offer its best function. (pp. 3–4)

These words, stated more than 30 years ago, hold true today. The challenge to occupational and physical therapists remains to clarify the relationship between proximal and distal motor control.

Existing research has been limited by the use of small samples. Another limitation relates to the sensitivity of the measures used. That is, the results of existing research suggest that the relationship between proximal and distal motor control may not be as direct.
as has been commonly assumed. Therefore, more sensitive measures may be necessary to identify a more indirect relationship. Finally, the observation that proximal motor functions generally develop before distal functions does not necessarily mean that proximal motor functions are prerequisite to the development of distal motor functions. Therefore, further investigation of the relationship between proximal and distal motor functions must control for the effect of age.

The purpose of this study was to investigate the relationship between proximal and distal motor control with a recently developed instrument that measures posture and fine motor control in infants. The following hypothesis was tested: Proximal and distal motor functions correlate significantly when the effect of age is controlled.

Method

Subjects

Sixty normal infants from day-care facilities in central Virginia were tested. The infants ranged in age from 2 through 6 months. The mean age of the sample was 4.4 months. The subjects were described as normal by their caretakers or by the day-care center staff. Visual and tactile functions were screened before testing, and all infants were within normal limits according to a screening protocol adapted from DeGangi (1987).

Instrumentation

Postural and fine motor control were measured by respective sections of the Posture and Fine Motor Assessment of Infants (PFMAI) (Case-Smith, 1987). The 46-item test rates fine increments of posture and movement (posture) as well as reach, grasp, and manipulation (fine motor) in the developmental sequence of normal 2- through 6-month-old infants.

Postural control includes automatic righting reactions, stability in antigravity positions, and controlled movements of the neck, shoulders, and pelvis. The Posture section of the assessment rates the infant's overall stability and mobility against gravity in both the supine and the prone positions. In addition to total posture scores, component scores, which we obtained by summing items that rated neck, shoulder, and pelvic mobility and stability in the prone and the supine positions, were also derived.

The Fine Motor section of the assessment measures the developmental level of reach, grasp, and manipulation of objects. This section includes approach to the object, accuracy of reach, accuracy of grasp, ability to maintain grasp, grasping pattern, and finger and thumb movement. In addition to total fine motor control scores, we obtained component scores for grasp and approach to object (reach) by summing related items of this section.

Interrater reliability of the PFMAI, assessed in 42 infants, is high; the intraclass correlation coefficients were .988 for the total posture scores, .989 for the total fine motor scores, and .989 for the total PFMAI scores. Test–retest intraclass correlation coefficients, based on the results for 33 infants, were .853 for the total posture scores, .913 for the total fine motor scores, and .936 for the total PFMAI scores (Case-Smith, 1989).

Procedure

The 60 infants were tested by the first author and four graduate occupational therapy students trained in PFMAI administration. The testing was performed in the day-care facilities, usually in a quiet room separate from the main play area.

The PFMAI is designed to be minimally intrusive to allow the examiner to observe the optimal behaviors of the infant. Assessment of infants through such naturalistic observation that does not require specific handling of the infant has been advocated in the literature (Harris, 1987). Milani-COMPARETTI (1982) proposed that observation of how the infant moves against gravity probably provides more reliable diagnostic information than does handling of the infant in an attempt to elicit a response.

In the Posture section of the PFMAI, the examiner rates posture by observing the infant's ability to independently sustain movement against gravity when both prone and supine. The examiner encourages progressively greater postural adjustments, reaching, and kicking by attracting the infant's attention to developmentally appropriate toys.

In the Fine Motor section of the PFMAI, the examiner repeatedly presents each of three objects to obtain the infant's best response. Different-sized objects (a pellet, a cube, plastic rings, or a toy helicopter) are used to elicit various grasping patterns and hand positions. The examiner offers the objects in his or her open palm to the infant, who is sitting semi-upright in an infant seat. Four minutes are allotted for reach and manipulation of each object. All items are rated on a 4-point scale, and the infant's best response is recorded.

Results

The means and standard deviations for the component and total posture and fine motor scores for the total sample, grouped by age, are listed in Table 1. As would be expected, all total scores on the PFMAI

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1 A copy of the Posture and Fine Motor Assessment of Infants may be obtained upon request from the American Occupational Therapy Foundation, 1383 Piccard Drive, Rockville, MD 20850-4375.
Table 1
Mean Scores and Standard Deviations of the Posture and Fine Motor Assessment of Infants by Age

<table>
<thead>
<tr>
<th>Test Section</th>
<th>Infants' Age (In Months)</th>
<th></th>
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<tr>
<td></td>
<td>2 (n = 9)</td>
<td>3 (n = 13)</td>
<td>4 (n = 14)</td>
<td>5 (n = 10)</td>
<td>6 (n = 14)</td>
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<tr>
<td></td>
<td>(n = 9)</td>
<td>(n = 13)</td>
<td>(n = 14)</td>
<td>(n = 10)</td>
<td>(n = 14)</td>
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<td><strong>POSTURE</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Head control</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>9.0</td>
<td>13.4</td>
<td>17.1</td>
<td>18.7</td>
<td>19.5</td>
</tr>
<tr>
<td>SD</td>
<td>2.4</td>
<td>2.3</td>
<td>2.8</td>
<td>1.5</td>
<td>1.1</td>
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<td>Shoulder control</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>M</td>
<td>6.1</td>
<td>8.4</td>
<td>11.4</td>
<td>14.5</td>
<td>15.4</td>
</tr>
<tr>
<td>SD</td>
<td>1.8</td>
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<td>2.0</td>
<td>1.7</td>
<td>0.8</td>
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<tr>
<td>M</td>
<td>11.1</td>
<td>13.0</td>
<td>16.6</td>
<td>21.0</td>
<td>24.7</td>
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<tr>
<td>SD</td>
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<td>2.5</td>
<td>3.2</td>
<td>5.5</td>
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<td>Total</td>
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<tr>
<td>M</td>
<td>37.6</td>
<td>50.2</td>
<td>63.8</td>
<td>76.2</td>
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<td>8.9</td>
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<td><strong>FINE MOTOR</strong></td>
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<tr>
<td>Approach to object/reach</td>
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<td></td>
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<tr>
<td>M</td>
<td>12.1</td>
<td>16.1</td>
<td>21.1</td>
<td>34.2</td>
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<tr>
<td>Grasp</td>
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<td></td>
</tr>
<tr>
<td>M</td>
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<td>15.6</td>
<td>27.1</td>
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<tr>
<td>SD</td>
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<td>4.5</td>
<td>3.5</td>
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<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>24.1</td>
<td>30.8</td>
<td>41.4</td>
<td>69.2</td>
<td>81.4</td>
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<tr>
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<td>9.4</td>
<td>14.0</td>
<td>10.5</td>
<td>9.4</td>
</tr>
</tbody>
</table>

were highly correlated with chronological age ($r > .89; p < .001$)

Therefore, to test the hypothesis that proximal and distal motor functions correlate significantly when the effect of age is controlled, partial Pearson correlation coefficients were computed for the PFMAI postural total and component scores and the PFMAI fine motor total and component scores. As shown in Table 2, all partial correlations, except those between the head control component of the postural and the total and component fine motor scores, were significant. The hypothesis was therefore accepted for all components except head control.

Discussion

The partial correlation between total posture scores and total fine motor scores indicates a positive relationship between proximal and distal motor functions. Although the relationship is significant, the correlation of $r = .350$ suggests that distal control is not strongly associated with proximal control. That is, only about 12% of the variance in the total fine motor scores was explained by the total postural scores.

A similar relationship was found between the postural shoulder and pelvic control component scores and the fine motor total and the fine motor component scores. The significant correlations between the shoulder and pelvic control scores and the total and component fine motor scores probably reflect the functional relationship, described by Ayres (1954/1974), that exists between these motor components.

Finally, the absence of a significant relationship between head control and the total and component fine motor scores suggests that the development of...
head control is independent of distal motor function. Although the literature defines head and neck control as a precursor of distal hand control (Bobath, 1971; Stockmeyer, 1967; Voss, 1972; Voss et al., 1985), it seems that this relationship is not present in normal infants when the effects of age are controlled.

Overall, these low, and sometimes nonsignificant, correlations are consistent with the results of the studies by Loria (1980) and Wilson and Trombly (1984) in that they do not provide strong support of the proximal–distal principle. They are not strong enough to imply that these two aspects of motor control are developmentally dependent. Although there appears to be a significant functional relationship, the expectation is that the correlations between the proximal and distal motor functions would be markedly higher if proximal motor control were necessary for the development of distal motor skill.

A significant statistical relationship does not imply a cause-effect relationship. Proximal and distal motor functions share a significant proportion of variance and nothing more. Conversely, one cannot conclude that because the relationships are not as strong as has been commonly assumed, Ayres’s logic is incorrect. A therapist needs only to observe clients with proximal instability and relatively good distal control (e.g., clients with corticospinal involvement from intracranial hemorrhage). Such clients can use only their distal skill when stabilizing their arms against their body or on a supporting surface. They cannot draw on a blackboard or obtain out-of-reach objects because they do not have the proximal musculature necessary for limb placement or reach. They have distal skill, but not distal function.

Clinical Implications and Recommendations for Further Study

The distinction between such a functional relationship and the cause-effect relationship postulated by the proximal–distal principle is critical to an interpretation of the clinical implications of this investigation. The proximal–distal relationship was based on the observation of normal children and then extrapolated to populations with motor disabilities. If proximal control is not significantly related to distal skill in normal children, it seems highly unlikely that such motor functions are related in children with atypical motor development. Clearly, there is a need to replicate this investigation with a sample of infants with established risk for central nervous system dysfunction and suspected disruption of the normal proximal–distal developmental progression.

If the proximal–distal motor development principle is not valid, we must critically examine certain aspects and techniques of the neurophysiological approaches that incorporate this principle. Treatment efficacy studies are needed that compare (a) treatment that focuses on the development of proximal control, (b) treatment that focuses on the development of distal control, and (c) treatment that addresses both problems concurrently. Until such efficacy research is implemented, we recommend that treatment programs focus on the observed deficits. Therapists should not assume that proximal control is a necessary precursor to fine motor skill; they should, however, assume that treating proximal weakness may affect distal function.

Summary and Conclusion

The results of this study suggest that, in normal children, there is a significant but weak relationship between proximal motor control and the development of distal motor skill. This suggests that the proximal–distal principle may not be a valid postulate on which to design treatment programs for persons with neurological disorders.

Although proximal stability and control may not be necessary for the development of distal skill, significant correlations do support the clinical impression that there is a functional relationship between proximal and distal motor functions. Therefore, therapists should not assume that treating deficits in proximal stability will result necessarily in the improvement of distal skill. Instead, therapists should treat both the proximal and distal motor deficits as separate, but functionally related, problems.

Acknowledgments

We extend our appreciation to Suann Zielinski, Elaine Meehans, Chwen-Yng Su, and Lynne Noyes for assisting in the data collection. We also thank Anita Bundy for her helpful review of the original proposal and earlier drafts of this manuscript.

This study was funded by a grant from the American Occupational Therapy Foundation.

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