Physical therapists frequently evaluate and teach patients to roll from a supine to a prone position. The purposes of this study were 1) to describe the rolling movements of adults and 2) to determine whether the movement patterns used to roll might represent different developmental steps within three body regions.

Thirty-six healthy adult subjects were videotaped during 10 trials of rolling from a supine to a prone position. Written descriptions of each subject's movements were reduced to general categorical descriptions of movement patterns for three body regions (upper extremities, lower extremities, and head and trunk). Stage theory criteria were used in an attempt to order the movement patterns into developmental sequences. The most common combination of movement patterns was used to describe adults' rolling action. Although stage theory criteria were not met, developmental sequences of movement patterns were proposed for the three body regions. Subjects were quite variable in their rolling movements. The most common form of rolling occurred in less than 12% of the subjects' trials. The descriptions of adults' rolling action gathered in this study provide physical therapists with a variety of movement patterns for teaching patients to roll. [Richter RR, VanSant AF, Newton RA: Description of adult rolling movements and hypothesis of developmental sequences. Phys Ther 69:63-71, 1989]

**Key Words:** Functional training and activities, Motor skills, Movement.

Physical therapy for patients with neurologic dysfunction often includes the evaluation and teaching of rolling movements. To determine the "quality" of the rolling pattern, rolling movements must be evaluated against some standard or norm. To date no reported research exists describing the movement patterns that adults use to roll. Although specific rolling movements have been recommended for use in treatment, whether these movements are valid representations of healthy individuals' movements is unknown. The purposes of this study were 1) to describe movement patterns used by adults to roll from a supine to a prone position and 2) to determine whether different movement patterns seen in three regions of the body might represent developmental steps within this rolling task.

**Background**

Gesell and Amatruda defined motor development as a continuous process that proceeds stage by stage in a systematic order. McGraw used the term "phase" to indicate observable, definable behaviors occurring during a specific period of time. Morgen recently, the term "stage" has been used as a more formal theoretical construct in motor-development literature. In this...
According to formal stage theory, stages are intransitive. Stage 1 always precedes stage 2, stage 2 always precedes stage 3, and so forth.\textsuperscript{10} Stages are also universal; given proper circumstances and enough time, all individuals will pass through the same sequence of stages.\textsuperscript{11} If stages were not universal, some stages could be skipped during the process of development.

VanSant used stage theory constructs to study the motor task of rising from a supine to a standing position.\textsuperscript{12} She assumed that motor behavior in the rising task developed in a universal and invariant order. Individuals were expected to demonstrate behavior characteristic of their developmental stage, and individuals in transition between stages were expected to demonstrate behavior of adjacent stages. Adopting a life-span perspective of development, VanSant applied these stage theory constructs in a study of adult subjects ranging in age from 20 to 35 years. The behaviors assumed to undergo developmental change were the movement patterns of different body regions. The movement patterns observed in the sample of adults were initially described for three body regions: 1) the upper extremities, 2) the axial region, and 3) the lower extremities. Descriptive categories of movement patterns were formed and then ordered into developmental sequences for each body region by examining the variability of the subjects when they performed several trials of the rising task.

A subsequent study of children performing the same task demonstrated that the results of the study of adults were useful for hypothesizing the developmental sequences of movement patterns for the rising task.\textsuperscript{13} By first studying adults, VanSant was able to approach the more time-consuming study of children with clearly defined hypotheses of developmental sequences.

Gesell and Amatruda,\textsuperscript{6} McGraw,\textsuperscript{7} and Shirley\textsuperscript{14} have described development within the task of rolling, but their developmental sequences do not completely describe the movement patterns used to roll. Their reports are also limited to descriptions of the rolling movements of infants and very young children.

**Method**

**Subjects**

The 7 men and 29 women participating in this study ranged in age from 20 to 29 years. The study sample consisted primarily of students at the Medical College of Virginia, Virginia Commonwealth University. Individuals who had exposure to physical therapy techniques that prescribe the form of rolling movements were not included in this study. Individuals who reported any orthopedic or neurological conditions (eg, pain or muscle soreness) that would interfere with rolling were excluded from the study. Each subject signed an informed consent form.

**Equipment**

To collect the data, the first author (R.R.R.) used a 1.22- × 1.83-m exercise mat, a videocamera* mounted on a tripod, and a videocassette recorder and tuner.\textsuperscript{7} The camera was elevated to a position about 1.8 m above the floor and was located about 3.3 m from the center of the exercise mat. The camera was positioned such that the optical axis was at a 61-degree angle with respect to the horizontal plane and at a 55-degree angle with respect to a line bisecting the mat longitudinally (Fig. 1). This configuration of camera and mat was used to obtain an overall view of the subjects' movement with just one camera.

**Procedure**

The first author collected all data. He asked subjects to lie on the mat and then gave the following instructions: "Lie on your back with your arms at your side and roll to your stomach as fast as you can. Ten trials will be videotaped. I will say, 'Ready, go!' When I say 'Go,' roll to your stomach as fast as you can." All subjects were requested to roll toward and over their left side because of the camera location. No effort was made to determine handedness of the subjects or to hypothesize or study the effect of handedness on performance of the rolling task.

Videotaping began about three to five seconds before saying, "Ready, go!" and stopped just after the subject reached the prone position. A rest interval of one minute or less between trials gave the rater sufficient time to change trial-number indicators.

**Data Reduction**

**Movement pattern description.** The videotape was played back through the videocassette recorder and a television monitor. About 30 images per second were available for analysis. The videocassette recorder had single-frame advance, slow-speed, and stop-action capabilities. We used all of these modes to analyze subjects' movements. The first author described movements across all trials and subjects for each of three body regions: 1) upper extremities (UEs), 2) head and trunk (HT), and 3) lower extremities (LEs). We then examined the written descriptions of the movement of the UEs during the 8th, 9th, and 10th trials, looking for similarities and differences in the written descriptions. Based on these comparisons, we developed preliminary descriptive categories of movement patterns for the UEs. These preliminary categories were refined by reviewing the videotapes of all subjects and trials. After refining the categorical descriptions of the UE movement patterns, the first author reviewed the videotapes and classified the UE

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movement patterns for all subjects and trials into an appropriate category. This same process was repeated to identify movement patterns and reduce the data for the HT and LE regions.

Objectivity procedures. The second author (AFV) independently categorized movement patterns of each body region in a set of 36 randomly selected trials. The results of her classification were compared with the first author categorization of the same trials to determine the percentage of exact agreement between raters. If less than 85% of exact agreement was obtained within a body region, we refined the movement pattern descriptions to resolve any possible ambiguities. Another set of 36 trials was selected, and we repeated the process until we attained at least 85% of exact agreement for classifying the movement patterns of each body region. The first author determined his intrarater exact agreement after attaining a minimum of 85% of exact agreement with the second author.

Data Analysis

Developmental sequences. We used the following procedure to hypothesize a developmental order of movement patterns for each body region within the rolling task. As with VanSant's study, the movement pattern categories were assumed to represent developmental elements or steps. Concentrating on a single body region, we analyzed the data from subjects who had varied their movement patterns during the 10 trials. We searched for an ordering of the patterns in which subjects varied only among adjacent patterns. An ordering that met this criterion could be hypothesized as an invariant and universal developmental sequence of movement patterns for that body region.

Description of adults' rolling action. A table was constructed to record the combinations of UE, HT, and LE movement patterns used by each subject during each trial. From these data, the most common combination of UE, HT, and LE action across all subjects and trials was determined. The percentage of occurrence of each movement pattern was also determined for each body region across all subjects and trials.

Results

Movement Pattern Categories

Four movement patterns were identified for each body region. The UE movement patterns were "Lift and Reach Below Shoulder Level," "Lift and Reach Above Shoulder Level," "Lift and Reach Horizontally," and "Lift and Reach Vertically." The HT movement patterns were "Reach Horizontally," "Reach Vertically," and "Reach Diagonally." The LE movement patterns were "Lift and Reach Horizontally," "Lift and Reach Vertically," and "Lift and Reach Diagonally."
Reach Above Shoulder Level," "Push and Reach," and "Push." The first two patterns are characterized by lifting and reaching of the right UE as the subject rolls over the left side. The major difference between these two patterns is the position the right hand reaches with respect to the left shoulder. The Push-and-Reach and Push movement patterns are characterized initially by maintained contact of the right UE against the support surface as the subject rolls. Later during the movement, these two UE patterns can be differentiated by the position of the right arm at side lying. In the Push-and-Reach pattern, the right arm is parallel to or in front of the body by the time the subject reaches side lying. In the Push pattern, the right arm remains behind the body at side lying. Detailed descriptions of each UE movement pattern are provided in the Appendix.

The HT movement patterns were "Aligned Pelvis and Shoulder Girdle," "Pelvis Leads," "Relationship Between Pelvis and Shoulder Girdle Changes," and "Shoulder Girdle Leads." In all four HT movement patterns, the head and trunk turn to the left, and the head may be raised from the support surface. The four patterns can be differentiated by the positions of the right shoulder girdle and pelvis during the movement. During two of the movement patterns, Pelvis Leads and Shoulder Girdle Leads, either the right pelvis or the shoulder girdle leads the other as the subject rolls past side lying. Of the remaining movement patterns, Aligned Pelvis and Shoulder Girdle is characterized by the right pelvis and shoulder girdle remaining aligned with each other as the subject rolls past side lying. The Relationship-Between-Pelvis-and-Shoulder-Girdle-Changes movement pattern is characterized by a change in the relative position of the right pelvis and shoulder girdle before the subject reaches side lying. Detailed descriptions of each HT movement pattern are presented in the Appendix.

The LE movement patterns are "Bilateral Lift," "Unilateral Lift," "Unilateral Push," and "Bilateral Push." An initial flexion of the LEs occurs in each pattern. One or both LEs are lifted from the support surface enabling differentiation of the Bilateral-Lift and Unilateral-Lift movement patterns. During Bilateral Lift both LEs are flexed and lifted off of the support surface, whereas in Unilateral Lift only one LE is lifted off of the support surface. The Unilateral-Push and Bilateral-Push movement patterns are defined by whether one or both LEs push against the support surface. Complete descriptions of the LE movement patterns are provided in the Appendix.

**Objectivity of Movement Patterns**

We achieved 92% of exact agreement between the first and second authors for classifying movement patterns of the UE and HT regions. We attained 88% of exact agreement for the LE region. Intrarater objectivity for the UE, HT, and LE components was 94%, 91%, and 86% of exact agreement, respectively.

**Developmental Sequences**

Upper extremity sequence. Analysis of the UE categorization indicated that only 18 of the 36 subjects varied their UE movement pattern during their 10 trials of rolling. The other 18 subjects did not vary their UE movement pattern. No ordering of the UE movement pattern categories was found in which all subjects varied only among adjacent

<table>
<thead>
<tr>
<th>Upper Extremity Patterna</th>
<th>Head-Trunk Patternb</th>
<th>Lower Extremity Patternc</th>
<th>Occurrence (%)</th>
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aB-Lift and Reach Above Shoulder Level, C-Push and Reach, D-Push.
bB-Pelvis Leads, C-Relationship Between Pelvis and Shoulder Girdle Changes, D-Shoulder Girdle Leads.
cA-Bilateral Lift, B-Unilateral Lift, C-Unilateral Push.
Arm Pattern
• Lift and reach above shoulder level

Head-Trunk Pattern • Shoulder girdle leads

Leg Pattern • Unilateral lift

trials. No permutation was found in which all 17 subjects varied only among adjacent movement patterns. Two orderings of the patterns had only two individuals who did not meet this criterion: 1) Aligned Pelvis and Shoulder Girdle, Pelvis Leads, Relationship Between Pelvis and Shoulder Girdle Changes, and Shoulder Girdle Leads and 2) Shoulder Girdle Leads, Relationship Between Pelvis and Shoulder Girdle Changes, Pelvis Leads, and Aligned Pelvis and Shoulder Girdle. We again consulted McGraw’s research report to ascertain whether either permutation corresponded to her findings. One of the possible developmental orders paralleled McGraw’s developmental sequence. The Aligned-Pelvis-and-Shoulder-Girdle pattern was similar to McGraw’s description of the earliest rolling pattern to develop. Movement between upper and lower spinal segments did not appear to be characteristic of this early phase. Our HT categorical description, Pelvis Leads, was similar to McGraw’s description of the second, or “spinal extension,” phase; in both instances, spinal or trunk extension is a characteristic feature. We hypothesized, therefore, that the developmental sequence for HT movement patterns was 1) Aligned Pelvis and Shoulder Girdle, 2) Pelvis Leads, 3) Relationship Between Right Pelvis and Shoulder Girdle Changes, and 4) Shoulder Girdle Leads.

Lower extremity sequence.
Thirty-one subjects varied among the LE movement pattern used during their 10 trials. The remaining 5 subjects did not vary in LE action across their 10 trials. As with the other two body regions, no permutation was found in which all subjects varied between adjacent LE movement patterns. Two permutations were found in which only one individual varied among non-adjacent categories: 1) Bilateral Lift, Unilateral Lift, Unilateral Push, and Bilateral Push and 2) Bilateral Push, Unilateral Push, Unilateral Lift, and Bilateral Lift. In the line drawing of McGraw’s earliest step in the development of rolling, the lower extremities appear to be flexing on the trunk. During the second phase of development, the foot on the occiput side pushes and moves into an extension pattern. Our Unilateral-Push movement pattern category describes a similar extension pattern. We selected the ordering of patterns that was most consistent with McGraw’s findings and hypothesized that the developmental sequence of movement patterns for the LEs was 1) Bilateral Lift, 2) Unilateral Lift, 3) Unilateral Push, and 4) Bilateral Push.

Description of Adults’ Rolling
Thirty-two different combinations of UE, HT, and LE movement patterns were exhibited by the 36 subjects. Eight of these movement-pattern combinations were seen in only one trial. Table 1 reports the percentage of occurrence of the most common combinations, or “profiles,” of body action observed across trials. Only combinations appearing on more than 5% of the trials are included. Four combinations of UE, HT, and LE movement patterns appeared in at least 10% of the 360 trials. Three of these four combinations involved the same UE and HT patterns and differed only in LE action. This common set of UE and HT action was characterized by the right UE being lifted off of the support surface and the hand being brought up above shoulder level as the right shoulder girdle led the trunk to side lying. This form of UE and HT action was combined with either a Unilateral-Lift, Bilateral-Lift, or Unilateral-Push pattern in the LEs. Figures 2 through 4 illustrate these three common forms of rolling. The fourth common pattern (Fig. 5) differed from the other three patterns in HT action, because the relationship between the shoulder girdle and pelvis changed before the subjects reached side lying. In this latter combination, LE action was characterized by a Unilateral-Push pattern.

The frequency with which each movement pattern category was observed across the 360 trials is reported in Table 2. The UE and HT movement patterns observed most frequently were also elements of three of the common combinations of movement patterns. The most common LE pattern was the Unilateral Push.

Discussion

Forming Developmental Sequences

The theoretical model used to form sequences was based on stage theory
constructs. According to these constructs, for a sequence to be valid, all individuals who show across-trial variation in their movements should vary only to adjacent steps in the proposed sequence. Roberton found that developmental sequences that withstood this criterion, called an adjacency criterion, were validated in a later longitudinal study. Sequences of development in which individuals varied to nonadjacent steps were not validated in later longitudinal studies.

A major difference between our work and that of Roberton is the age of the subjects. Roberton used children as subjects when identifying developmental sequences. Since Roberton's initial work, however, VanSant identified developmental sequences of movement patterns using stage theory criteria with a group of adult subjects. Before undertaking that study, she postulated, however, that it may not be possible to use the adjacency criterion for adult subjects. VanSant hypothesized that adults may have developed all of the possible movement patterns and, therefore, may vary among all movement patterns. Because in this study a developmental sequence could not be identified in which all subjects varied among adjacent steps, it is possible that our subjects also varied among any of the patterns identified, as proposed by VanSant. If adults vary among all movement patterns, however, then it is curious that possible sequences were identified in which such small numbers of subjects varied among nonadjacent patterns. The sequences identified in this study may represent the common, if not universal, orders of development of movement patterns for this task. That is, they may represent a developmental order seen in a majority of, but not all, individuals.

**Validating Developmental Sequences**

Roberton proposed that developmental sequences not meeting the criterion used in this study may need further revisions before beginning a longitudinal study of the development of movement patterns in the task. Our results indicate that the movement patterns we identified and the developmental sequences proposed should undergo further study. A cross-sectional design sampling several different age groups would be the most practical next step. Such a study would provide data to support or refute the developmental nature of the movement pattern categories by determining whether the incidence of these patterns varies with age. In addition, the developmental sequences we proposed could undergo preliminary screening by studying the order in which the patterns predominate with respect to age. The ultimate method of supporting or refuting the developmental nature of the movement patterns is a longitudinal study, which could document changes in movement patterns as they occur over time.

**Clinical Implications**

The high number of movement pattern combinations appearing in our study sample should alert physical therapists to the great variability of movement patterns that can be used to roll. This knowledge gives therapists more options to use when training or retraining adults in the task of rolling. The categorical descriptions of
The movement pattern descriptions developed in this study are somewhat similar to the patterns of movement described by Knott and Voss in their text on proprioceptive neuromuscular facilitation. For example, in the PNF description of rolling from a supine to a prone position while stressing UE movement, the leading UE moves in a pattern incorporating shoulder extension, adduction, and medial (internal) rotation. The Lift-and-Reach-Below-Shoulder-Level UE movement pattern is similar to this PNF diagonal pattern of extension, adduction, and medial rotation. The Lift-and-Reach-Above-Shoulder-Level UE movement pattern and the UE PNF pattern of flexion, adduction, and lateral (external) rotation are also similar to one another. This similarity is most apparent in the description of the flexion, adduction, and lateral rotation pattern during a procedure to facilitate head, neck, and trunk rotation while rolling.

In summary, we believe that the wide variability in movement patterns used by adults to roll from a supine to a prone position should be considered when teaching patients to roll. Future studies should be undertaken to determine whether the different movement patterns identified in this study present different developmental steps within the task of rolling and whether the sequences proposed here are valid.

**Conclusions**

Adults show great variability in the movement patterns used to roll. We hypothesize that the movement patterns identified in this study are developmental; that is, we propose that these movement patterns vary with age. Finally, we do not believe that the sequences of movement pattern development hypothesized for each body region will be seen in all individuals. Rather, we believe that the sequences represent a common order of development demonstrated by most, but not all, individuals.

**References**

Appendix.  Adult Rolling Movement Patterns

Upper Extremity

Lift and Reach Below Shoulder Level
The right upper extremity (UE) is lifted off of the support surface and reaches across the body with the right hand at or below shoulder level. The left arm stays at the side of the body, abducts, or may be lifted off of the mat. The left shoulder or UE contacts the support surface as the subject rolls over the left shoulder or UE.

Lift and Reach Above Shoulder Level
The right UE is lifted off of the support surface. The right hand is brought above shoulder level. The left arm may stay at the side of the body. The subject rolls over the left UE or shoulder.

Push and Reach
At the start of the movement, part of the right UE appears to push while in contact with the support surface. The right UE is lifted from the support surface as the right shoulder flexes, reaching toward a position parallel to or in front of the body when the subject is side lying. The left arm may stay at the side of the body, and the left shoulder or UE remains in contact with the surface as the subject rolls.

Push
The right UE maintains contact with the support surface as the right shoulder extends. The right arm remains behind the body until the subject reaches side lying. The left arm may stay at the side of the body, abduct, or flex. The left shoulder or UE remains in contact with the support surface as the subject rolls past side lying.

Head and Trunk

Aligned Pelvis and Shoulder Girdle
The head and trunk turn to the left. The head may be raised from the support surface, and the trunk may flex as the subject rolls. The right pelvis and shoulder girdle remain aligned with each other beyond the side-lying position.

Pelvis Leads
The head may be raised off of the support surface and may turn to the left. The trunk turns to the left. The right pelvis leads the right shoulder girdle, and this relationship stays the same beyond side lying. The trunk becomes extended before side lying.

Relationship Between Pelvis and Shoulder Girdle Changes
The head may be raised off of the support surface and may turn as the trunk rotates to the left. The right shoulder or pelvis may initially lead the movement toward side lying and may be aligned with each other. Before side lying, the relative position of the right pelvis and right shoulder girdle changes.

Shoulder Girdle Leads
The head may be raised from the support surface and may turn to the left. The trunk rotates to the left and may flex before side lying. The right shoulder girdle leads the right pelvis, and this relationship stays the same beyond side lying.

Lower Extremity

Bilateral Lift
Both of the lower extremities (LEs) are flexed and lifted off of the support surface with the right pelvis remaining on the support surface. The LEs may be carried to the left and may not reach full extension.

Unilateral Lift
One or both LEs may flex and assume a position as if to push. One LE may be lifted off of the support surface. If the right LE is lifted off of the support surface, this movement occurs before any part of the right pelvis loses contact with the support surface. Neither extremity, although contacting the support surface, maintains a fixed point of contact against which to push.

Unilateral Push
The right LE is pulled up toward the chest, remaining partly in contact with the support surface. One foot maintains a fixed point of contact on the support surface and appears to push.

Bilateral Push
Both LEs are pulled up toward the chest. Both feet simultaneously maintain a fixed point of contact with the support surface and appear to push. As the subject rolls to side lying, the right leg or thigh may remain behind the left LE.
