The Relationship between the Movement Patterns of Rising from a Supine Position to an Erect Stance and Physical Functions in Healthy Children

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In early childhood, the movement patterns used in rising from a supine position to an erect stance are asymmetrical at first, but develop toward symmetry as the child grows older. However, the relationship between strength and balance and these developmental changes remains unclear. The purpose of this study was to determine the relationship between the choices of movement patterns in rising from a supine position to an erect stance and physical functions in healthy children. Sixty-eight children without any disabilities and whose mean age was 4 y 11 mo were videotaped while performing the rising motion. The motion was classified as either asymmetrical or symmetrical. Physical functions such as muscle strength and standing balance were also assessed. The Mann-Whitney U-test and an analysis of covariance (AN-COVA) with age as covariates were used to compare the asymmetrical and symmetrical groups with respect to the children's physical functions. Children who demonstrated symmetrical movement patterns had significantly greater grip and trunk muscle strength, and longer duration of one-leg standing than did children who showed asymmetrical movement patterns. According to ANCOVA, the symmetrical movement patterns were explained by a positive relationship to grip strength and trunk flexor strength. Our findings suggested that muscle strength was related to the acquisition of symmetrical movement patterns of rising from a supine position to an erect stance, in healthy children.

Keywords: Motor Development; Rising from a Supine Position; Physical Functions

Introduction

Movement patterns in childhood, such as those used in rising from a supine position, rolling over, and gait, alter with age (VanSant, 1990). For young children, rising to a standing position is an important step toward developing independence (Marsala & VanSant, 1998). Clinicians should evaluate children's ability to rise from a supine position to an erect stance and encourage children to improve this ability or, when it is lacking, acquire it (VanSant, 1988).

Previous research examining the movement patterns of this motion in children revealed that younger children tend to use asymmetrical movement patterns such as the involvement of full or partial rotation of the trunk until the trunk reaches either a prone position or a side-facing position, while older children tend to use symmetrical movement patterns such as trunk with no rotation (VanSant, 1990; Marsala & VanSant, 1998; VanSant, 1988; Nakano et al., 2007). In addition, several researchers (Schaltenbrand, 1927; Milani-Comparetti & Gidoni, 1967; Alexander et al., 1995; Kaneko et al., 2003) have studied movement patterns associated with physical functions in infants, toddlers, and older people. Schaltenbrand (1927) and Milani-Comparetti and Gidoni (1967) suggest that in infants and toddlers this task may be affected by postural responses. Alex-

ander et al. (1995) state that in older adults, trunk flexor strength and flexibility are related to the variation in movement patterns of rising from a bed. Kaneko et al. (2003) find that flexibility is related to such patterns, and that lateral reach and trunk flexor strength are determining factors for the amount of time required for performing this task in older people.

A number of questions remain about the relationship between the choices of movement patterns in rising from a supine position to an erect stance and physical functions in healthy children, including which factors are related to movement pattern changes in children, and whether factors reported to be associated with these patterns in older people are the same as those influencing the movement patterns observed in children. If the factors associated with movement patterns were identified, it might help to clear the mechanism of the movement pattern change with age in healthy children. And, it might help clinicians to evaluate and treat individuals who are unable to carry out this motion.

The primary purpose of the present investigation was to examine the relationship between physical functions such as strength and balance and the choice of movement patterns in rising from a supine position to an erect stance in children. Our secondary purpose was to determine whether muscle strength and standing balance were associated with these movement

patterns, independent of their relationship with age, since it is reported that these functions are strongly influenced by age (Tokyo Toritsu Daigaku, 2000; Booth et al., 1994; Bohannon et al., 1984; Toriola & Igbokwe, 1986; Malina et al., 1995)

Methods

Subjects

The sixty-eight children (26 males, 42 females; mean age, 4 y 11 mo, SD = 11 mo, range = 3 y 5 mo to 6 y 5 mo) who participated in this study had no obvious physical or mental disorder (**Table 1**). The children attended kindergarten in Kanagawa Prefecture, Japan. Written consent for study participation was obtained after the purpose of the study was explained to the children's families. The study protocol was approved by the Research Ethics Board at the Research Ethics Committee, The Society of Physical Therapy Science.
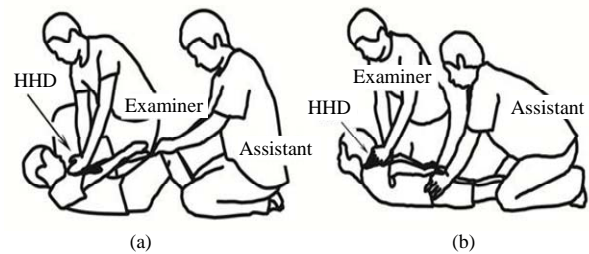
Physical Function

Muscular Strength

Grip strength (kg): The grip strength of each hand was measured using a grip dynamometer for children, the Smedley Dynamometer (Matsumiya Ika Seiki Seisakusho Co., Ltd., Tokyo, Japan). While standing, the child held the dynamometer at his or her side with the arm hanging down from the shoulder and the elbow extended, and squeezed it with maximal force. The grip strength of each hand was measured 3 times, and the maximum values of the 6 trials were then used in subsequent statistical analyses.

Trunk flexor and extensor strength (N): Trunk flexor and extensor strength were measured using a hand-held dynamometer (HHD), the Micro FET2 (Hoggan Health Industries, Inc., UT, USA). To measure trunk flexor strength in the children, we had the child being tested lie on an exercise mat in the supine position. The child then sat up without the support of the upper extremities, while his or her knees and ankles were held immobile by an assistant. The Micro FET2 was applied on the child's sternum to measure trunk flexor strength (**Figure 1(a)**). To measure trunk extensor strength in each child, we had the child lie on an exercise mat in the prone position. The child extended the trunk upon instruction, while his or her pelvis and knees were held immobile by an assistant. The Micro FET2 was applied on the child's interscapular region (**Figure 1(b)**). Trunk flexor and extensor strength were measured 3 times for each child. The maximum value of each item was processed in subsequent statistical analyses.

Table 1.
Characteristics of the subjects.

Age	3 years (n = 17)		4 years (n = 17)		5 years (n = 17)		6 years (n = 17)	
Sex	Boys (n = 5)	Girls (n = 12)	Boys (n = 13)	Girls (n = 4)	Boys (n = 13)	Girls (n = 4)	Boys (n = 13)	Girls (n = 4)
Heigth[a] (cm)	99.7 (6.4)	97 (3.5)	101.9 (5.4)	102.8 (5.6)	110.3 (5.0)	108.6 (3.8)	115.2 (3.3)	114.8 (5.9)
Weight[a] (kg)	15.4 (2.8)	14.2 (1.5)	16.1 (2.1)	15.7 (1.4)	18.6 (2.4)	20.2 (4.8)	19.4 (1.6)	21.4 (4.3)

Note: [a]Mean value (SD).

Figure 1.
Methods of measuring physical functions. Trunk flexor strength, (a); Trunk extensor strength, (b).

Balance

We chose to evaluate static balance, because dynamic balance tests using a force platform (Doyle et al., 2008) or a functional reach test (Duncan et al., 1990) require complex instructions and are therefore less valid measures in young children.

One-leg standing time (sec): The duration of one-leg standing time was measured as an indicator of static balance. We measured the amount of time, up to a maximum of 30 sec, during which the children could maintain standing on one leg. The one-leg standing time was measured 3 times, and the maximum value was used in subsequent statistical analyses.

Videotaping of the Movement Patterns of Rising from a Supine Position

We used the videotaping method described by VanSant (1988). Briefly, two digital video camera recorders (DCR-PC101, Sony, Inc., Tokyo, Japan) located at the children's feet and side were used to record the children's motion when rising from a supine position to an erect stance. One camera was placed perpendicular to the length of the mat, and the other, perpendicular to its width. Each camera was placed on a tripod 340 cm from the center of a 192 × 118 cm exercise mat, and at a height of 60 cm from the floor.

As recording started, two light signals were emitted by a synchronizing system (Synchronizer PH-100, DKH Co., Ltd., Tokyo, Japan) to synchronize the two video cameras. The synchronized video images were recorded simultaneously by a video editing program (Ulead Video Studio 7, Ulead System, Inc., Kanagawa, Japan) so that the movement patterns could be appropriately classified.

Regarding instructions for filming, each child lay on the exercise mat in the supine position and was then ordered to stand up. No other instructions were given concerning how to perform this motion or how quickly to do it. After 3 practice trials, the children were filmed performing the task until they had done 5 trials successfully. The task was judged as successful if the child accomplished it himself or herself without stopping or playing during the task.

Statistical Analysis

The Mann-Whitney U-test was used to compare the asymmetrical and symmetrical groups with respect to the children's ages and physical functions. An analysis of covariance (ANCOVA) with age (months) as the covariate was used to compare the two movement pattern groups for physical functions. When conducting the ANCOVA, we examined muscle strength and balance for homogeneity of variance to evaluate interaction

(Group × Physical Functions). Examination of the physical functions revealed that interaction was excluded from the AN-COVA. A p value of <.05 was considered to indicate statistical significance. All statistical analyses were performed on a personal computer using the statistical package SPSS for Windows, Version 19.0 (SPSS Japan, Inc., Tokyo, Japan).

The Mann-Whitney U-test was used to compare age and physical functions between the asymmetrical and symmetrical groups. Asterisks indicate significant differences between the 2 groups ($^{**}p < .01$; $^{*}p < .05$).
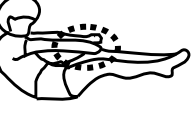
Results

Comparison of Age and Physical Functions between the Two Groups

Table 3 shows a comparison of age and physical functions

between the asymmetrical and symmetrical groups in the 3 bodily regions based on the Mann-Whitney U-test. The mean age of the children in the symmetrical group was significantly greater than that in the asymmetrical group in all 3 regions. The mean ages of the asymmetrical group were 4 y 8 mo in the upper extremity region, 4 y 4 mo in the axial trunk region, and 4 y 6 mo in the lower extremity region, while the mean ages of the symmetrical group in the 3 bodily regions were 5 y 10 mo ($p < .001$), 5 y 1 mo ($p = .004$), and 5 y 1 mo ($p = .029$), respectively.

For the upper extremity region, grip strength ($p < .001$), trunk flexor strength ($p < .001$), and trunk extensor strength ($p < .001$.) for those in the symmetrical group were significantly greater than these same measures in the asymmetrical group. Additionally, the one-leg standing time ($p = .012$) of the symmetrical group was significantly longer than that of the asymmetrical group. In the axial trunk region, the grip strength (p

Table 2.
Categories of movement patterns associated with the asymmetrical and symmetrical group.

Upper extremity region

Asymmetrical group — Step 1: Push and reach to bilateral push; Step 2: Asymmetrical push

Symmetrical group — Step 3: Symmetrical push; Step 4: Symmetrical reach

Axial trunk region

Asymmetrical group — Step 1: Full rotation, abdomen down; Step 2: Full rotation, abdomen up; Step 3: Partial rotation

Symmetrical group — Step 4: Forward with rotation; Step 5: Symmetrical

Lower extremity region

Asymmetrical group — Step 1: Jump to squat; Step 2: Half kneel

Symmetrical group — Step 3: Asymmetrical wide-based squat; Step 4: Symmetrical narrow-based squat

Table 1.
Comparison of age and physical functions between the asymmetrical and symmetrical groups in the 3 bodily regions.

Age and physical functions	Upper extremity region		Axial trunk region		Lower extremity region	
	Asymmetrical	Symmetrical	Asymmetrical	Symmetrical	Asymmetrical	Symmetrical
	(n = 56)	(n = 12)	(n = 19)	(n = 49)	(n = 21)	(n = 47)
Age	4 y 9 mo	5 y 8 mo[*]	4 y 9 mo	5 y 0 mo[*]	4 y 6 mo	5 y 1 mo[*]
	(2.0 mo)	(2.2 mo)	(6.5 mo)	(1.9 mo)	(4.2 mo)	(1.9 mo)
Grip strength (kg)	4.4	6.9[**]	4.5	5.1[**]	5	5
	(0.3)	(0.4)	(1.0)	(0.3)	(0.6)	(0.4)
Trunk flexor strength[a] (N)	41.1	65.2[**]	45.5	46.9[**]	42.8	47.8
	(2.9)	(4.4)	(7.9)	(3.2)	(6.8)	(3.3)
Trunk extensor strength[a] (N)	72.6	95.8[**]	72.6	78.7[**]	72	79.7
	(4.7)	(3.5)	(14.0)	(4.3)	(10.5)	(4.3)
One-leg standing time[a] (sec)	14.2	24.4[**]	14.2	16.9	15.2	17
	(1.8)	(3.1)	(5.6)	(1.8)	(3.8)	(1.9)

Note: [a]Mean value (SD).

= .001), trunk flexor strength (p = .002), and trunk extensor strength (p = .008) of the symmetrical group were significantly greater than those of the asymmetrical group, but there were no significant differences between the two groups in one-leg standing time (p = .080). In the lower extremity region, the children in the symmetrical group were older than those in the asymmetrical group, but no significant differences in physical functions were identified.

## Comparison of the Physical Functions of the Two Groups Using an ANCOVA with Age as the Covariate

An ANCOVA with age (months) as the covariate was performed on the muscle strength and balance factors that showed significant differences on the Mann-Whitney U-test for the upper extremity and axial trunk regions. In the upper extremity region, one-leg standing time was excluded from the analysis, because there was interaction (Group × One-leg standing time, p = .026) in the homogeneity of variance. Because there were no significant differences between movement patterns and physical functions in the lower extremity region, this region was excluded from the ANCOVA.

The results of the ANCOVA showed that grip strength (p = .004) and trunk flexor strength (p < .001) were significantly different for the two groups showing symmetrical or asymmetrical patterns in the upper extremity region, while trunk extensor strength did not differ between the groups showing symmetrical or asymmetrical patterns (**Figure 2**). No significant differences in physical functions were detected between the symmetrical and asymmetrical groups in the axial trunk region (**Figure 3**).

Discussion

Comparison of Age and Physical Functions between the Symmetrical and Asymmetrical Groups

The mean age of the children demonstrating symmetry of movement patterns was significantly greater than that of the asymmetrical group for all 3 bodily regions, at 5 y 8 mo in the
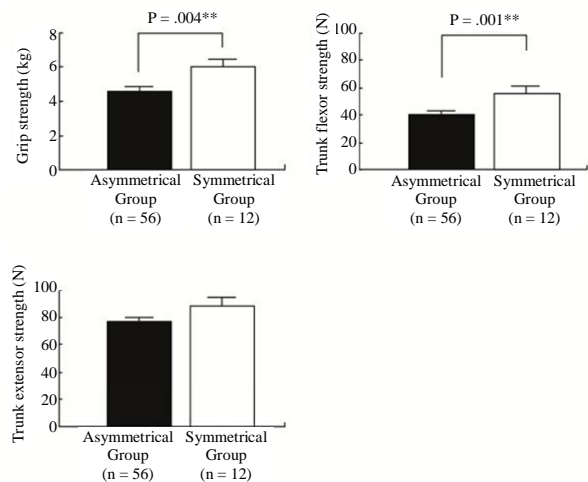
Figure 2.
Comparison by an analysis of covariance (ANCOVA) with age (months) as the covariate physical function values, between the asymmetrical and symmetrical groups in the upper extremity regions. Mean ± SD was estimated by ANCOVA. One-leg standing time was excluded from the analysis, because there was interaction (Group × One-leg standing time, p = .026) in the homogeneity of variance.

upper extremity region, 5 y 0 mo in the axial trunk region, and 5 y 1 mo in the lower extremity region, vs. 4 y 9 mo, 4 y 9 mo, and 4 y 6 mo, respectively, in the asymmetrical group. Milani-Comparetti and Gidoni (1967) state that in healthy children, symmetrical movement patterns emerge around 5 years of age. In the present study, it was clear that the movement patterns were related to age; thus, it was important to adjust for age in considering the movement patterns.

With respect to the relationship between muscle strength and balance and movement patterns, our findings revealed that the muscle strength and balance function were significantly different between the asymmetrical and symmetrical groups. In the upper extremity and axial trunk regions, the muscular strength and balance measures of the symmetrical group were significantly greater than those of the asymmetrical group. Several
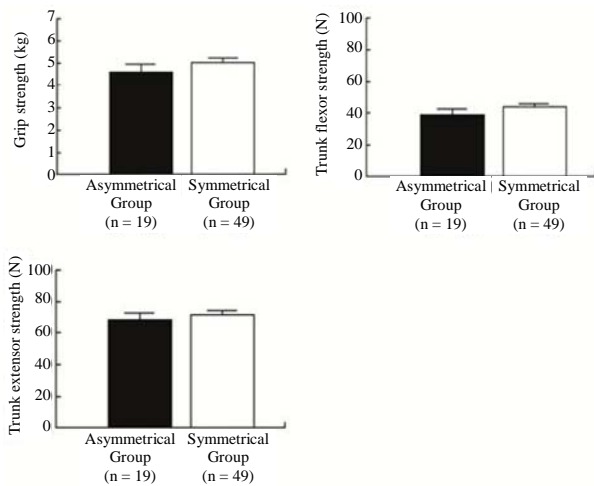
Figure 3.
Comparison by an analysis of covariance (ANCOVA) with age (months) as the covariate physical function values, between the asymmetrical and symmetrical groups in the axial trunk regions. Mean ± SD was estimated by ANCOVA based on the values of the physical functions.

researchers (Alexander et al., 1995; Kaneko et al., 2003) who have studied movement patterns associated with rising in older people found that muscle strength and balance are related to movement patterns in these populations as well. In the present study, symmetrical movement patterns of rising from a supine position were found to be related to muscle strength and balance in healthy children.

In the lower extremity region, only age affected movement pattern changes; physical functions were not significantly different between the two groups. In the present study, we did not measure the lower-limb muscle strength, but we speculated that the movement patterns in the lower extremity region were affected by the lower-limb muscle strength. We measured one-leg standing time as a measure of static balance. If we had measured dynamic balance, we might have found a relationship between movement pattern differences in the lower extremity region. Because individuals were reported to show great variability with regard to the movement pattern in the lower extremity region (Nakano et al., 2007), we speculated that this movement pattern was affected by various physical functions such as muscular strength, balance, and flexibility.

Comparison of Physical Functions between the Symmetrical and Asymmetrical Groups Using an ANCOVA with Age as the Covariate

We used ANCOVA to clarify what physical functions other than movement patterns are affected by age, because the development of muscle strength and balance shows a strong correlation with age (Bohannon et al., 1984; Toriola & Igbokwe, 1986; Malina et al., 1995; Doyle et al., 2008). Our results revealed that only grip strength and trunk flexor strength correlated with the movement patterns in the upper extremity region. Nishimoto et al. (1989) analyzed surface electromyography of healthy adults moving to sitting from the supine, side lying, and prone positions and found that the muscle activity of the sternocleidomastoideus and abdominals is greatest when the subjects are rising from the supine position. The authors hypothesized that weakness of these two axial trunk region muscles

causes vicarious motions of the deltoids and triceps to produce weight-bearing in the upper limbs. Their results suggested that if healthy children had sufficient trunk muscle strength, they could rise without weight-bearing on the upper limbs, but if they were deficient in muscle strength in this area, the upper extremities would be used to compensate. In the present study, movement patterns in the upper extremity region were found to be related to muscle strength, independent of their relationship with age. In the trunk axial region, the muscular strength of members of the symmetrical group tended to be greater than that of members of the symmetrical group, but the difference was not significant. Milani-Comparetti and Gidoni (1967) wrote that the degree of trunk rotation in the movement patterns of the axial trunk region was explained by age. We speculated that the movement pattern differences in the trunk axial region were influenced a great deal by age.

The results of this study suggest that muscular strength affected the process of acquiring a symmetrical movement pattern when rising from a supine position. We believe that children should be taught that improved muscle strength is important for acquiring the rising motion. Additionally, instruction on how to perform asymmetrical movement patterns is very useful for those with weak muscles who are acquiring or re-acquiring the ability to rise from the supine position.

Limitations

The present study had several limitations. First, it was a correlation analysis, and no cause-and-effect relationship between muscle strength and movement patterns could be confirmed. A longitudinal analysis would be needed to clarify the influence of muscle strength on movement pattern changes during childhood. The factors that were measured were also limited, and muscle strength of the lower extremity region and overall flexibility were not assessed. More factors that may relate to the performance of the rising motion need to be identified. Although we found great individual differences in muscle strength and balance among the children studied, we only tested 68 subjects between the ages of 3 y 5 mo and 6 y 5 mo; thus, the third limitation was the number of subjects as well as the subjects' limited age range. The ability to rise from a supine position to an erect stance is established during the first 12 months of life (Milani-Comparetti & Gidoni, 1967; Ueda, 1983; Illingworth, 1991). The present study, however, did not include children under 3 years of age or older than 6 years 5 months. In future research, the relationship between muscle strength and movement patterns in this task must be studied in younger and older subjects as well as in children with disabilities.

Acknowledgements

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