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Original Article

# The Characteristics of Sit-to-stand Movement in Infants aged 1 Year: A Preliminary Study

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Sit-to-stand (STS) movement requires coordinated movement of multiple body segments. However, the kinematic characteristics of STS movement in infants have not been fully clarified. The purpose of this study was to assess the kinematic characteristics of STS movement in infants. Six infants aged 12 to 14 months and 6 adults aged 21 to 22 years old took part in this study. In order to assess STS movement, a motion analysis system consisted of 2 cameras was used. STS movement data which included the duration from initial point to hip off the seat (Phase I) of STS movement and angular movement of each joint (trunk, hip, knee, and ankle) were collected. To compare the sampled data, Mann-Whitney U-test was used. Statistical significance was set at $P<0.05$. The duration time of Phase I of the infant group significantly increased compared with that of the adult group ($P<0.05$). The transitional trunk angular movement significantly decreased in the infant group compared with that of the adult group ($P<0.05$). On the other hand, the transitional hip and ankle angular movement significantly increased in the infant group compared with that of the adult group ($P<0.05$). These findings suggest that the pattern of STS movement in the infants is characterized by not only less trunk inclination, but also less hip flexion motion and more ankle dorsiflexion. These observed movements exemplify how infants are able to stand from sitting position independently.

**Key words :** sit-to-stand movement; motion analysis; infant

## 1 Introduction

Sit-to-stand (STS) is one of the important movements for infants to develop, and this ability is a necessary prerequisite for walking. STS movement requires forward and upward displacement of the body's center of mass from a larger to a relatively smaller base of support. Moreover, adequate body balance, equilibrium reaction and coordination of muscle activation are required simultaneously[1]. However, infants would have some difficulty in accomplishing this movement, due to their immature equilibrium function. Thus, understanding how infants performed STS movement independently is invaluable information in making a rational evaluation of motor development of disabled children, such as cerebral palsy.

There have been few studies on motion analysis of infant's STS movement[2,3]; hence, the kinetic and kinematic characteristics of STS movement in infants have not been clarified fully. Cahill's study[2] has reported that younger infants (12-18 months) had the smallest trunk inclination and higher angular trunk flexion velocity. McMillan's study[3] has also suggested that infants would have larger trunk inclination with age. In this manner, one of the features of infant's STS movement would be smaller trunk inclination. However, this hypothesized feature would lead us to one important question. If infants could not incline their trunk fully, their body's center of mass would not also be shifted forward. Therefore, it was hypothesized that infants would shift the body's center of mass forward by utilizing different strategies.

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The purpose of this study was to assess the kinetic and kinematic characteristics of STS movements in infants.

## 2 Methods

*2.1 Subjects*

Six infants (2 males and 4 females), aged 12 to 14 months, and were able to walk independently, participated in this study. In addition, all infants attained independent walking within 3 months. The infant subjects included a preterm and/or low birth weight infants. Jeng has reported that preterm infants attained independent walking at significantly older age than term infants, after corrected age for prematurity [4]. Infants in this study showed no difference in Apgar scores [1-and-5 min] and delay of motor development (Table 1); as such, all infants have almost the same motor function.

Moreover, 6 adults (3 males and 3 females), aged 21 to 22 years old, who had no history of neurological and/or orthopedic diseases, participated. This research study was conducted after having obtained the approval of Osaka Prefecture University Research Ethics Committee (2011-P05). The purpose of this study was explained to the infant's parents and adult subjects orally, and written consent were obtained.

*2.2 Materials*

A chair with no arms or backrest and as high the subject's knee joint in sitting position was prepared. The size of the support surface of this chair was 40 cm wide × 30 cm long.

An originally developed pressure-sensitive trigger device (30 cm wide × 20 cm long × 3 mm thick), which helps to detect the point of hip off the seat, was placed on this chair. This device can record loss of contact with the seat by detecting when subjects' weight is reduced by less than 3 kg.

In order to assess subject's STS movement, a motion analysis system using a motion analyzer with 2 digital cameras (Kinema tracer: made by Kissei Comtec, Japan) (30 fps), which was synchronized to this trigger device, was used. Each camera was placed on the dominant oblique and lateral side.

*2.3 Movement procedures*

Markers were placed unilaterally on the following body landmarks: lateral malleolus, lateral femoral condyle, greater trochanter, and acromion. Since the infants could not understand fully our verbal commands and/or movement procedures, each parent gave verbal encouragements and various gestures in each STS trial. Thus, each parent sat in front of the child, within 1-meter-distance. This procedure was similar as in Cahill's study[2]. Moreover, the infants were permitted to perform STS movements as they preferred. STS movements were performed more than 5 times in bare feet, with a brief pause between each trial. Equally important, infant subjects have a difficulty in standing still [2]. Therefore, the infants were allowed to take two or three steps forward.

*2.4 Analysis procedures*

For the purpose of data analysis, one trial was selected. The inclusion criteria were as follows: (i) trunk and bilateral lower thighs were erect as straight as possible; (ii) sole of the feet to the floor; and (iii) hands resting between the thighs. The subjects were instructed to stand up from the chair without using their arms to push up to standing position. Then, STS movement data which included the duration of STS movement, angular movement and angular velocity were collected.

The end point of STS was not defined in this study since the infants have difficulty in standing still [2]. Therefore, only the duration time from the initial point of STS (T1) to hip off the seat (T2) (Phase I) was calculated. The initial point of STS (T1) was defined as the point when the marker of acromion started to move, and the hip off the seat point of STS (T2) was measured from the data on our developed trigger device and was defined as the point when the waveform is located in first lowest electrical voltage (Fig. 1).

As for the angular movement, the angles which included trunk, hip, knee, and ankle segments were collected. Angular movement of trunk was defined as between the lines from the acromion to greater trochanter and the vertical line (Z-axis) through the greater trochan-

Table 1 The profile of infant subjects

| | Age (months) | Sex | Height (cm) | Weight (kg) | Gestational age (week) | Birth weight (g) | Apgar score (1/5min)(points) | Independent sit-to-stand (months) | Independent walking (months) |
|---|---|---|---|---|---|---|---|---|---|
| A* | 12 | Female | 73 | 7.4 | 35 | 1658 | 8/9 | 9 | 11 |
| B* | 12 | Male | 72 | 9.3 | 34 | 1716 | 8/9 | 9 | 11 |
| C | 13 | Female | 72 | 8.8 | 40 | 2804 | 8/9 | 11 | 13 |
| D | 13 | Female | 73 | 10.2 | 37 | 2164 | 8/9 | 9 | 12 |
| E | 14 | Female | 75 | 9.8 | 38 | 3342 | 8/9 | 11 | 13 |
| F | 14 | Male | 76 | 9 5. | 39 | 3040 | 9/10 | 8 | 11 |

* Age and motor development were presented by corrected age

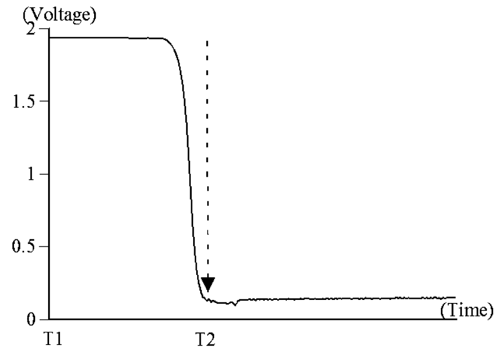


Fig. 1 The definition of hip off the seat (T2)
Vertical and horizontal axis demonstrate electrical voltage, time, respectively. The electrical voltage records approximately 2 voltages when the subject's buttocks are on the chair. This device can record loss of contact with the seat by detecting when subjects' weight is reduced by less than 3 kg.

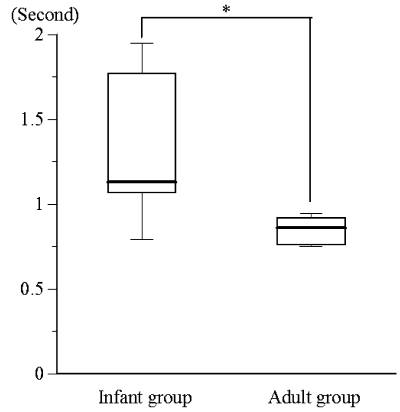


Fig. 2 The duration time of Phase I
Vertical axis indicates second. *: P<0.05

Table 2 Angular movement of each segment on the initial point (T1)

| Angular movement (Degree) | Infant group (n=6) | Adult group (n=6) | P value |
|---|---|---|---|
| trunk | 8.9 ± 2.2 | 6.6 ± 1.7 | n.s. |
| Hip | 102.0 ± 3.1 | 97.8 ± 1.7 | n.s. |
| knee | 98.9 ± 4.1 | 94.5 ± 1.2 | n.s. |
| Ankle | 6.9 ± 5.0 | 7.0 ± 1.5 | n.s. |

Data are presented as Mean ± SED
n.s.:not significant

ter. In a similar way, angular movement of hip was defined as between the line from the acromion to greater trochanter and the line from the greater trochanter to the lateral femoral condyle. Angular movement of knee was defined as between the line from the greater trochanter to the lateral femoral condyle and the line from the lateral femoral condyle to the lateral malleolus. Angular movement of ankle was defined as between the line from the lateral femoral condyle to the lateral malleolus and the vertical line (Z-axis) through the lateral malleolus. These settings were similar as in our previous study[5]. Then, the angle of the 4 segments at T1 and T2 was calculated.

Trunk inclination and ankle dorsifexion in STS movement shift the body's center of mass forward[1, 6]. Consequently, these segments assessed not only the angular movement, but also the maximum positive peak angular velocity in Phase I.

In the analysis, SPSS version 16 was used. Due to small sample size, nonparametric analysis (Mann-Whitney U-test) was selected for comparing the infant and the adult group. P-value less than 0.05 was considered statistically significant.

## 3 Results

### *3.1 The duration time*

The duration time of Phase I of the infant group significantly increased compared with that of the adult group (P = 0.030)(Fig. 2). The Median [min-max] time of Phase I of the infant group was 1.13 [0.76 - 1.97] seconds; that of the adult group was 0.86 [0.75 - 0.95] seconds.

### *3.2 Angular movement*

There was no significant difference on the 4 segments of initial angular movement in the two groups (Table 2).

As for the transitional angular movement, there was no significant difference on knee segment in the two group (P=0.234); whereas there was significant difference at the other 3 segments (Table 3, Fig. 3).

The transitional trunk angular movement of the infant group significantly decreased compared with that of the adult group (P=0.009). The Median [min-max] transitional trunk angular of the infant group was 37.6 [11.4 - 51.5] degrees, and that of the adult group was 55.5 [45.3 - 60.1] degrees (Fig. 3A).

On the other hand, the transitional hip angular movement of the infant group significantly increased compared with that of the adult group (P=0.009). The Median [min-max] transitional hip angular of the infant group was 84.2 [63.4 - 101.1] degrees, and that of the adult group was 58.0 [56.2 - 71.0] degrees (Fig. 3B).

The transitional ankle angular movement of the infant group also significantly increased compared with that of the adult group (P=0.041). The Median [min-max] transitional ankle angular of the infant group was 20.0 [9.8 - 25.3] degrees, and that of the adult group was 13.4 [6.9 - 18.0] degrees (Fig. 3D).

### *3.3 Angular velocity*

The maximum positive peak of trunk angular velocity of the infant group significantly decreased compared with that of the adult group (P=0.004). The Median [min-max] maximum positive peak of trunk angular velocity of

Table 3 Angular movement of each segment on hip off the seat (T2)

| Angukar movement (Degree) | Infant group (n=6) | Adult group (n=6) | P value |
|---|---|---|---|
| Trunk | 37.0 ± 6.1 | 54.4 ± 2.0 | ** |
| Hip | 85.3 ± 5.6 | 61.3 ± 2.7 | ** |
| Knee | 99.4 ± 3.7 | 99.1 ± 1.6 | n.s. |
| Ankle | 19.1 ± 2.3 | 12.4 ± 1.7 | * |

Data are presented as Mean ± SED
n.s.:not significant
*: P<0.05 **: P<0.01

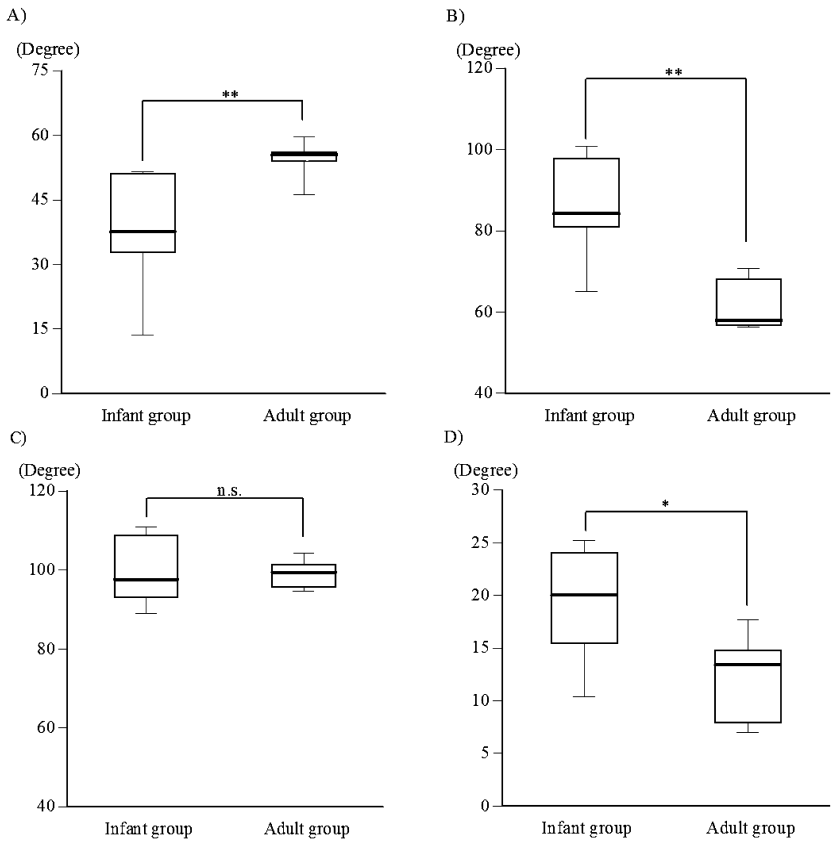


Fig. 3 The angular movement of each joint on T2
Vertical axis indicates degree. A), B), C) and D) show the angular movement of trunk, hip, knee, and ankle, respectively. *: P<0.05 **: P<0.01 n.s.: not significant

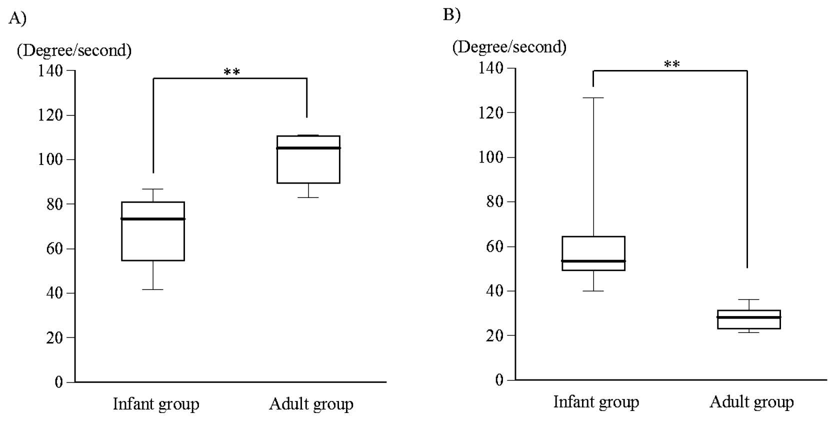


Fig. 4 The maximum peak angular velocity in Phase I
Vertical axis indicates degree/second. A) and B) show the maximum peak angular velocity of trunk and ankle, respectively. **: P<0.01

the infant group was 75.3 [40.1 - 87.5] degrees/second, and that of the adult group was 105.2 [82.1 - 111.2] degrees/second (Fig. 4A).

On the other hand, the maximum positive peak of ankle angular velocity of the infant group significantly increased compared with that of the adult group (P=0.002). The Median [min-max] maximum positive peak of ankle angular velocity of the infant group was 53.4 [38.9 - 133.8] degrees/second, and that of the adult group was 28.3 [21.1 - 36.6] degrees/second (Fig. 4B).

## 4 Discussion

The present study focused on the kinetic and kinematic characteristics of STS movement in infants. The findings indicate that the pattern of STS movement in infants is characterized by shortened duration in Phase I, less hip flexion motion and more ankle dorsiflexion, and higher ankle angular velocity, compared with that of the adults'. In the following paragraphs, the features of STS movement in infants will be discussed.

Trunk inclination in STS movement shifts the body's center of mass forward from the buttocks to the feet, which propels seat off the hip [1,6]. If for some reason this movement is restricted significantly, STS movement would be performed by various compensatory patterns [5,7,8,9]. In this study, trunk angular and angular velocity of infant's STS movement at T2 showed significantly lower angular movement and velocity than that of adults'. These findings have been reported by Cahill's study [2]. Thus, the infant subjects might have also difficulty in shifting the body's center of mass forward. This presumption explains for the longer duration of Phase I.

In order to shift the body's center of mass forward, the infants tilted their lower thighs forward larger and sooner instead of utilizing trunk inclination. In general, tilting lower thighs forward has been caused by trunk inclination [6]. This motion helps to produce hip flexion moment to shift the body's center of mass forward and upward [1,6]. Although knee angular movement at T2 between the 2 groups had almost similar angle, the infants could not flex their hip segments fully, due to immaturity. This phenomenon indicated that STS movement in infants could not generate hip flexion moment. Therefore, STS movement in infants might be more heavily dependent on these lower thighs motions than those in adults. In other words, it could be assumed that STS movement in infants was characterized by less selective muscle control. This presumption was explained by McMillan's study [3], which has reported that infants performed their STS movement by not only little trunk inclination but also by sliding their buttocks forward at earlier stage.

These findings lead us to conclude that the pattern of STS movement in the infants is characterized by not only less trunk inclination, but also less hip flexion motion and more ankle dorsiflexion. These observed movements exemplify how infants are able to stand from sitting position independently.

The limitation of the present study is high variability of STS movement in infants. Several researchers [3,10] have reported that STS movement within children has high variability. Therefore, the kinetic and kinematic characteristics of STS movement in infants have not been fully clarified. To have a better understanding of STS movement in infants, more infant subjects are needed in future study.

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