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Differences in the motion of typically developing children aged 4–6 years putting on trousers in a standing position

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Abstract

This study was designed to assess differences in the motion of putting on trousers in a standing position in typically developing children aged 4–6 years, and to find a relation between it and single-leg standing.

Participants in this study were 50 typically developing children (28 boys and 22 girls; 4.5 ±0.4 years, 5.5±0.3 years, 6.6±0.3 years). They performed two tasks: 10 s single-leg standing and putting on trousers in a standing position.

Based on the motion characteristics, the motions of putting on trousers were classified three types. Compared to types 1 and 2, type 3 showed that participants flexed their trunk, grasped the waistline of the trousers near the support leg knee, and fixed the trousers and extended swing leg to fit the trousers. These motion characteristics decreased the total time, path length, and anterior-posterior（AP）maximum displacement while putting on trousers. Moreover, the age increased as the type changing from 1 to 3. When standing on a single leg, the single-leg standing time increased, as did the path velocity, the AP and medial-lateral direction velocity and maximum displacement decreased as the type changing from 1 to 3.

These results suggested that the three types motion of putting on trousers in a standing position matured by age for typically developing children aged 4–6 years. The types were related with the ability to stand on a single leg.

Key words：Center of pressure, Dressing, Putting on trousers, Typically developing children

Introduction

Dressing requires children to have different performance skills and patterns[1)]. Children often dress themselves in clothes when they go to nursery school, kindergarten, and elementary school. Moreover, children sometimes change clothes before and after playing outside at a nursery school or kindergarten. Japanese children aged 6–7 years enroll in elementary school and take physical education classes. Children change their clothes and prepare for physical education during short breaks between classes.

A recent study in Japan showed that parents of children in groups with developmental delay, access to counselling support, and access to specialized facilities reported more difficulty for their children in changing

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Table 1 Profile of participants.

Age group (n)	Age (month)	Height (cm)	Weight (kg)	Foot length (cm)	Foot width (cm)
4 (12)	53±4	102.8±4.6	16.8±1.7	12.9±0.6	6.3±0.5
5 (19)	65±3	110.3±4.2	19.2±1.9	13.9±0.9	6.4±0.5
6 (19)	78±3	115.1±4.1	20.8±2.3	15.0±1.1	6.8±0.5

Mean ± Standard deviation

clothes than a control group[2,3]. These parents help with the difficulty of changing clothes. Moreover, the establishment of self-independence in childhood was positively correlated with prosocial behavior and negatively correlated with hyperactivity, behavioral problems, emotional instability, and friendship problems in the middle of elementary school[4]. Promoting self-independence from an early age has a positive effect on adaptation to school life after entering elementary school.

On the other hand, Naik and Summers et al[5,6] reported that parents of children with autism spectrum disorders (ASD) and developmental coordination disorder (DCD) have difficulty in changing clothes. First, buttons and fastenings were difficult. Second, it took time for the child to distinguish the front, back, left, and right of the clothes. Third, the children made an effort to put on trousers in a standing position. Therefore, these children took more time to change clothes than typically developing children. Some researchers have reported that children with ASD and DCD have greater difficulty with posture control on a single leg and double legs than typically developing children[7,8,9]. These findings indicated children of ASD and DCD had difficulty controlling the standing posture. For that reason, they sat down to put on their trousers. Additionally, they needed parental support because it took a long time to put their foot through the leg of the trousers.

By contrast, 4-year-old typically developing children perform independent dressing and stands on a single leg for an average of 5 s[10,11]. In dressing, the motion of putting on trousers in a standing position is the combination of standing on a single leg and putting on trousers. However, the independence of putting on trousers in a standing position and the relation between posture and putting on trousers in a standing position remain unclear.

This study was designed to assess differences in the motions of putting on trousers in a standing position in typically developing children aged 4–6 years, and to find the relation between the putting on trousers in a standing position and single-leg standing.

Methods

Participants

Participants were 50 typically developing children (28 boys, 22 girls) who were 4–6 years. They belonged nursery school in Yamagata, Japan. They and their parents read the guide and decided voluntary to participate in this study. Inclusion criteria were children who had no pre-existing health condition or cognitive or musculoskeletal difficulty affecting the task, who put on trousers in a standing position, and who completed the task to the end. Detailed information of the participants was shown in Table 1.

All participants and parents gave their informed consent to the experimental procedures, which were approved by the Ethics Committee of Yamagata Prefectural University of Health Sciences (September 27, 2018., No. 1809-18).

Instrumentation and date acquisition

The analysis parameters were the motion of tasks, foot pressure, and center of pressure (COP). Each task was recoded from the frontal plane and the right sagittal plane using two video cameras (C920; Logitech International SA, Lausanne, Switzerland). Time resolution of the video camera was 30 Hz. The spatial resolution was 998,400 pixels (1,280×780). The experiment trousers used for motion of putting on trousers in a standing position were 100% polyester trousers (2285030; Caroline Corp., Nagoya, Japan).

Each participant put on experiment trousers of 100 cm, 110 cm, 120 cm, 130 cm, and 140 cm depending on the child's height.

Foot pressure and COP were measured using a foot pressure platform (platform, EM-MP2703; Noraxon USA, Arizona, USA). This had time resolution of 100 Hz. The spatial resolution was 16 bits. The 40 cm × 57 cm platform was placed with the short side vertical to the frontal plane camera and the long side was horizontal. The platform was calibrated at the time of setup. The displacement of COP was that the short side of the platform was in the anterior–posterior (AP) direction. The long side was in the medial–lateral (ML) direction.

All devices were synchronized using software (MR3 ver.3.12; Noraxon USA, Arizona, USA). The software was also used for measurement and analysis.

Tasks

All participants performed two tasks. Task 1 was to stand on a single leg for 10 s maximum. Participants stood upright on each single leg with eyes open. The upper limbs position was left up to each participant. Task 2 was the motion of putting on trousers in a standing position. The speed of motion was self-selected.

Procedures

A quiet room at a nursery school was used for the study. Participants entered the room and received an explanation of the task. Subsequently, they stood upright on the platform. The measurement was performed in the order of Tasks 1 and 2. For Task 2, participants took off their own trousers that they had already worn. Next, they put on and took off the experimental trousers. Finally, they put on their own trousers. Both tasks were measured once. All tasks were completed in about 10 min. During the measurement, each participant rested accordingly.

Definitions of terms

The terms for the analysis were defined and used. The first swing leg was the leg to pass through the trousers first. It was defined as the First Leg (FL). The Second Leg (SL) was defined the next swing leg of the FL. It passed through the trousers later. The support leg while passing FL through the trousers was defined the First Support Leg (FSL). The Second Support Leg (SSL) was defined the next support leg of FSL and had already passed through the trousers.

The foot pressure and COP position were explained by the separate soles (Figure 1). The heel side was half of the foot length from the heel. The toe side was the side anterior to the heel side. Furthermore, the inside was the half of foot width from the innermost part of the sole. The outside was the lateral side from inside.

Motion phase

Task 2 was divided into five phases based on the video date (Figure 2a). Phase 1 (P1) was defined between the beginning of the motion of putting on trousers (image 1) and the FL before it left the floor. P1 was the period from image 1 to immediately before image 2. Phase 2 (P2) was defined from the time FL started to lift (image 2) to passing of the leg through the trousers. P2 was the period from image 2 to immediately before image 3. Phase 3 (P3) was defined the duration from when the FL reach the floor until the

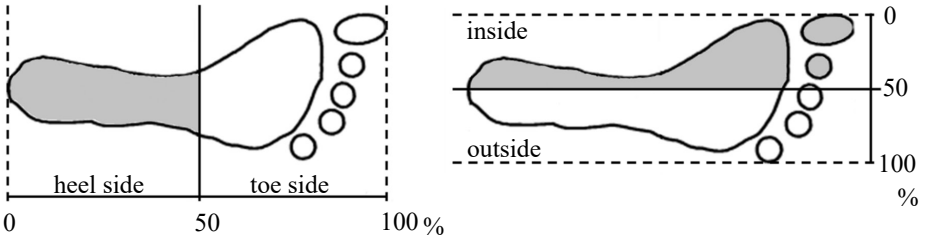

Figure 1 Explanation of foot pressure distribution and COP position

The images on the left divided into toe side and heel side by 50% of foot length, and on the right divided into inside and outside by 50% of foot width.

SL before it moved. P3 was the period from image 3 to immediately before image 4. Phase 4 (P4) was defined from the time the SL left the floor to passing through the trousers. P4 was the period from image 4 to immediately before image 5. Phase 5 (P5) was defined the duration from the SL reach the floor until the waistline of the trousers were pulled up to the waist to finish the motion of putting on trousers. P5 was therefore the period from image 5 to 6.

The P2 and P4 were divided into three small phases (Figure 2b). The first small phase of P2 and P4 (P2-1, P4-1) was shown between the beginning the motion of FL and SL, and it raised to the waistline of trousers. The P2-1 and P4-1 were the periods from image a or v to immediately before image b or w. The second small phase (P2-2, P4-2) was the duration from starting to put the foot in the trousers until the foot was completely in the trousers. The P2-2 and P4-2 were periods from image b or w to immediately before image c or x. The start of the third small phase (P2-3, P4-3) was the FL and SL started to extend. The end was the ending motion of FL and SL. The P2-3 and P4-3 was the period from image c or x to image e or z.

Data analysis

The authors confirmed the reproducibility of the motion procedure from the video data in Task 2. The data of motion, foot pressure, and COP data while putting on the experimental trousers were analyzed. First, two occupational therapists (OT) listed characteristics from all the video data of the putting on trousers in a standing position. Second, two OTs

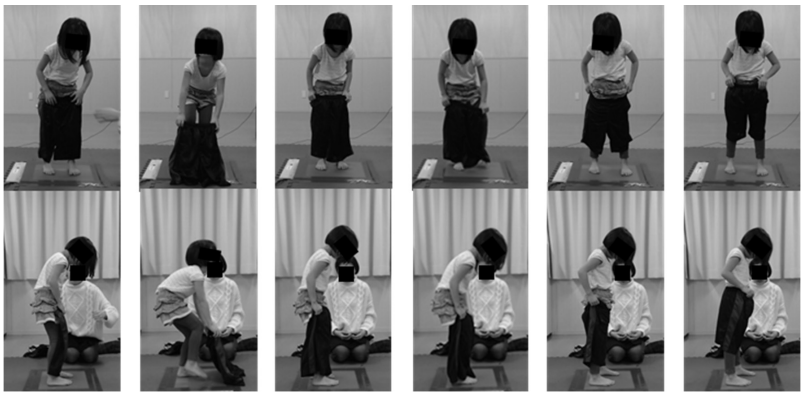

Figure 2a Photographic playback of putting on trousers in a standing position.

The top indicated the frontal plane images, and the bottom indicated the sagittal plane images. Image 1 indicated the beginning of motion in putting on trousers. Image 2 and 3 indicated the beginning and the ending first leg (FL) motion. Image 4 and 5 indicated the beginning and the ending second leg (SL) motion. Image 6 indicated the ending motion in putting on trousers. Abbreviations for the images as well as Figure 2b.

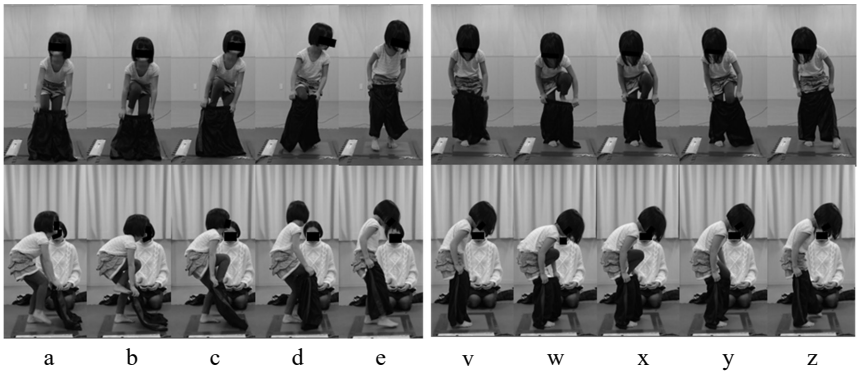

Figure 2b Detail motion images of phase 2 (P2) and 4 (P4).

Motion of P2 indicated left side images (from a to e). Motion of P4 indicated right side images (from v to z). Left side of P2 and P4 indicated the beginning of motion FL and SL (a and v). Second of P2 and P4 indicated the beginning put foot in trousers (b and w). Third of P2 and P4 indicated the beginning extension FL and SL (c and x). Forth P2 and P4 indicated the ending extension FL and SL (d and y). Fifth P2 and P4 indicated the ending of motion FL and SL (e and z). Abbreviation in this as well as Figure 3 to 5.

Table 2 Characteristics of each type motion of wearing trousers.

Type 1	Type 2	Type 3
● Put swing leg on the floor during motion ● Hook foot on the trousers and repeated the same procedure ● Grasped the waistline of the trousers using one hand ● Flexed the trunk slightly ● Flexed the hip and knee joints of the swing leg greatly	● Grasped of the waistline of the trousers in a higher position than the support leg knee using both hands ● Fixed the swing leg and pulled up the waistline of the trousers to fit swing leg	● Grasped of the waistline of the trousers near the support leg knee using both hands ● Fixed the trousers and extended swing leg to fit the trousers

Column indicated the type of putting on trousers and line indicated characteristics of motion of wearing trousers.

examined and decided the criteria for classification of putting on trousers in a standing position. Moreover, the characteristics were classified into three types. Finally, three OTs classified all participants into three types based on criteria from video data. In the type classification judgment, all or two OTs matched.

Based on the type of putting on trousers, the analysis items were age, single-leg standing time, and total time and single-leg standing time while motion of putting on trousers. Furthermore, the motion, the foot pressure, and COP while putting on trousers and single-leg standing were analyzed using video and platform data. The foot pressure was observed in the spatial distribution on the platform. The low data of COP were calculated from the displacement distances of the COP in the AP and ML direction. The path length was the sum of the total AP length and total ML length (cm). The path length was divided by the time and designated path velocity (cm/s). The path velocity was divided into the AP and ML direction. The velocities in the AP and ML directions were calculated by dividing the path length of each direction by the time (cm/s). The maximum displacement of AP and the ML direction were calculated from the linear distance between the maximum and minimum values of AP and ML (cm). The path length, AP maximum displacement, and ML maximum displacement were divided by height, foot length, and foot width of each participants, respectively[12]. Therefore, the path length and the AP and ML maximum displacement were standardized.

Statistical analysis

The single-leg standing time and COP of the Task 2 were used in FSL (P2) and SSL (P4). The single-leg standing time, path length, path velocity, and the AP and ML direction velocity and maximum displacement of Task 1 and Task 2 were used by summing each leg. Kendall's coefficient of concordance W was used to estimate the homogeneity of the type of putting on trousers. Fisher's exact test were applied to the classification of types and ages. The Kendall rank correlation coefficient was used for correlation between types and the analysis items. Significance level was set at 5% for all tests. All statistical analyses were performed using software (SPSS ver. 24; IBM Corp., Armonk, NY, USA).

Results

Type classification of putting on trousers (Table 2)

Participant A showed the motion of putting on

trousers on P2 and P4 in Figure 3.

The start of P2 was the posture for which the waistline of the trousers was grasped higher than the pelvis (Figure 3, image a). The high foot pressure and COP position indicated the heel side. As shown in image b (Figure 3), participant A grasped the waistline of the trousers in a higher position than the FSL knee. Therefore, the hip and knee joints of FL greatly flexed, and the trunk flexed slightly. The foot pressure was divided to the heel and inside of the toe side. The COP was displaced from the posterior to the anterior direction. Then, the trunk bent lateral to the FL side (Figure 3, image c). The high foot pressure deviated to the toe side. The COP was displaced in a more anterior direction. Image d showed extension of the hip and knee joints of FL. The foot pressure increased on the heel side. The COP was displaced to the posterior direction again. At the end of P2 (Figure 3, image e), participant A pulled up the waistline of the trousers with both hands. The foot pressure expanded the sole of the foot. The COP was displaced in the anterior direction.

At the start of P4 (Figure 3, image v), participant A grasped the waistline of the trousers with only the hand on the SL side. Moreover, the trunk flexed slightly. The high foot pressure and COP position indicated the heel side. On image w (Figure 3), the upper limb on the SSL side abducted, and the foot of SL reached the waistline of the trousers. The foot pressure deviated to the toe side. The COP was displaced greatly from the posterior to the anterior and lateral direction. Then, the upper limb of the SSL side was lowered (Figure 3, image x). In addition to image w, the deviation of foot pressure expanded slightly to the heel side of the outside. The COP was displaced slightly to the posterior direction. Image y (Figure 3) showed extension of the hip and knee joints of the SL. The foot pressure increased on the outside. The COP was displaced to the posterior and lateral direction. At the end of P4 (Figure 3, image z), participant A pulled up the waistline of trousers with only the SL side hand and started to grasp the waistline of the trousers with the SSL side hand. The foot pressure and COP position were similar to those shown in image y.

In single-leg standing (Task 1), the right side and left side time of participant A were 8.2 s and 10.0 s, respectively. Furthermore, participant A abducted both upper limbs horizontally and showed posture sway such as lateral bending of the trunk, and adduction and internal rotation of the support leg hip joint, and adduction–abduction and internal–external rotation of the swing leg hip joint in single-leg standing position.

Mentioned above, participant A flexed the trunk slightly, greatly flexed the hip and knee joints of the

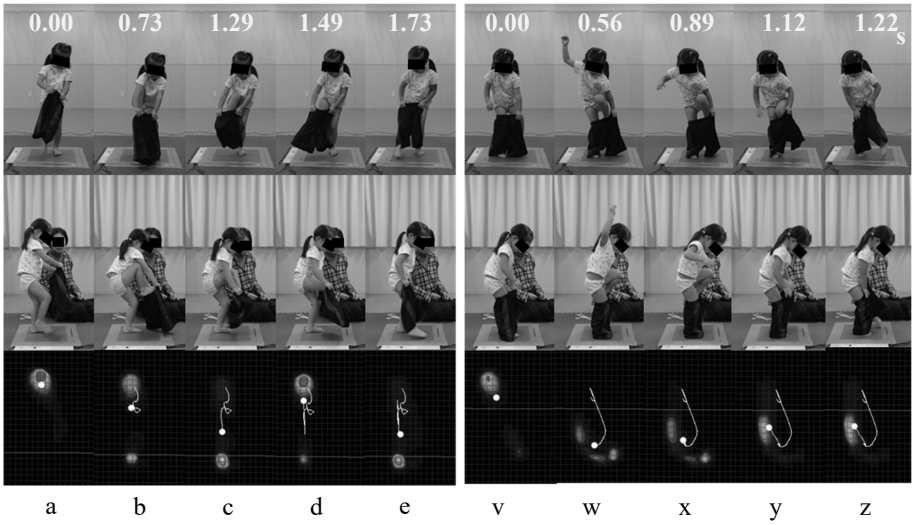

Figure 3 Motion images indicated the participant A of P2 and P4.

The bottom indicated the foot pressure and center of pressure (COP) of the foot pressure platform. Low foot pressure indicated blue color and high foot pressure indicated green color. White circle and line in each picture were COP position and COP trajectory. Abbreviations in this as well as Figure 4 and 5.

swing leg and grasped the waistline of the trousers using one hand in P2 and P4. The foot pressure of participant A was divided and deviated. The COP was displaced greatly in the AP direction. Participant A, who showed such motion characteristics was classified into Type 1. Other participants who performed similar motion characteristics on P2 or P4 were also classified as Type 1. In addition, other participants performed clear imbalance, such as putting their swing leg on the floor during motion, hooking their foot on the trousers and repeating the same procedure in P2 or P4. These were also classified as Type 1. The motion characteristics of Type 1 were shown in Table 2.

Eighteen participants showed these motion characteristics. Of them, fourteen participants abducted their upper limbs to maintain balance while standing on a single leg (Task 1). The total times on a single leg of Type 1 participants were 3.0 s–20.0 s, with a median of 16.1 s.

Participant B showed the motion of putting on trousers on P2 and P4 in Figure 4.

The posture of participant B at the start of P2 was the same as that of participant A (Figure 4, image a). The foot pressure deviated to the heel side and the inside of toe side. The COP position was on the heel side. On image b (Figure 4), the posture for which the waistline of the trousers was grasped higher than the FSL knee was shown, similarly to participant A. However, participant B abducted and external rotated the FL hip joint. Compared with participant A, the foot pressure was more expanded to the outside. The COP was displaced from the posterior to the anterior and in a slightly lateral direction in the middle of the foot. Image c (Figure 4) showed participant B fixed the FL and moved the trousers to fit FL. Then, participant B extended the hip and knee joints of the FL and pulled up the waistline of the trousers (Figure 4, image d–e). During these times, the foot pressure indicated the heel side and inside of the toe side, as well as on the outside and the sole of the foot. The COP was displaced in each direction of AP and ML in the middle of the foot. The COP of participant B in the AP direction showed a shorter displacement than that of participant A.

At the start of P4 (Figure 4, image v), the posture of participant B was the same as that of participant A, whereas participant B grasped trousers with both hands. The foot pressure indicated on the sole of the foot. The COP position was on the heel side. On Image w (Figure 4), the posture such as that of participant B grasped the waistline of the trousers higher than the SSL knee, greatly flexed the SL hip and knee joints, and flexed the trunk slightly were similar to image b of participant A. However, participant B bent the trunk to the SSL side. Image x to z (Figure 4) showed that participant B extended the hip and knee joints of SL to fit the trousers. During these times, the foot pressure deviated to the heel side and inside of the toe side, similarly to images b to d of participant A. Nevertheless, the COP displacement in the AP direction

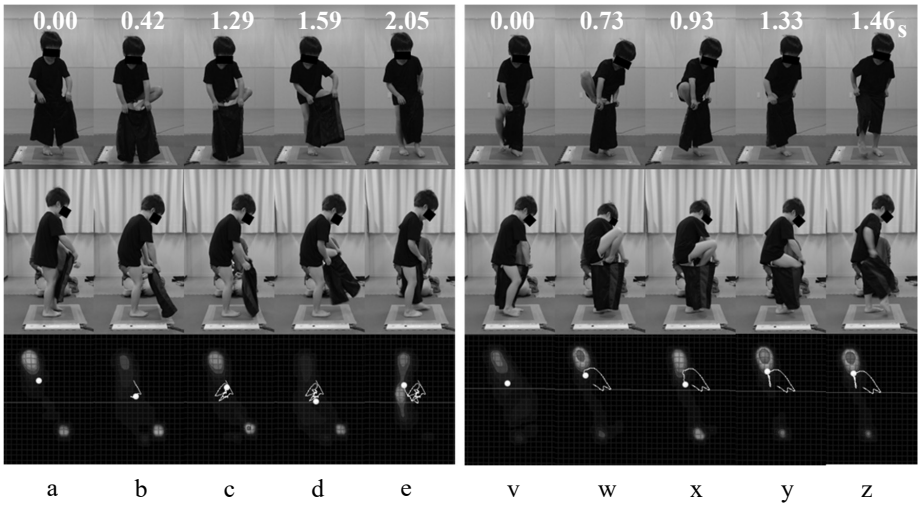

Figure 4 Motion images indicated the participant B of P2 and P4.

was decreased more than for the participant A.

In single-leg standing (Task 1), the right side and left side time of participant B were 10.0 s and 7.2 s, respectively. Furthermore, participant B bent the trunk lateral slightly, and adducted and abducted of the upper limb on the support leg side on each leg. However, swing leg and support leg hip movements of participant B were less than that of participant A.

Mentioned above, participant B performed the motion with grasping of the waistline of the trousers in a higher position than the support leg knee, and fixed the swing leg and pulled up the waistline of the trousers to fit swing leg in either P2 or P4. The foot pressure of participant B indicated not only deviation and division but also outside and the sole of the foot. The COP displacement decreased more in the AP direction than for participant A. Participant B, who showed such motion characteristics was classified into Type 2. Other participants who performed similar motion characteristics on P2 or P4 were also classified as Type 2. In addition, no Type 2 participant put their swing leg on the floor during motion and did not repeat the same procedure in P2 and P4. The motion characteristics of Type 2 were shown in Table 2.

Twenty participants showed these motion characteristics. Of these, eight participants abducted their upper limbs to maintain balance while standing on a single leg (Task 1). The total times on a single leg of Type 2 participants were 9.6 s–20.0 s, with a median of 17.6 s.

Participant C showed the motion of putting on trousers on P2 and P4 in Figure 5.

At the start of P2 (Figure 5, image a), the posture of grasping the waistline of the trousers in near the FSL knee different from that of participant B. As shown in image b (Figure 5), participant C grasped the trousers with both hands near the FSL knee and raised the FL to the waistline of the trousers. The foot pressure expanded to the toe side and outside. The COP was displaced from the medial to lateral direction. Then, participant C fixed the waistline of the trousers and extended the hip and knee joints of the FL to fit the trousers, different from participant B (Figure 5, image c–e). During these times, the foot pressure increased on the heel side and inside of the toe side as well as indicated on the outside and the sole of the foot. These foot pressure distributions differed from image b to d of participant A. The COP was displaced in the middle of the foot in each direction of AP and ML.

At the start of P4 (Figure 5, image v), the posture and foot pressure of participant C were similar to those shown in image v of participant B. In contrast, the COP position of participant C was on the middle of the sole. Then, participant C fixed the waistline of the trousers near the SSL knee and extended the hip and knee joints of the SL to fit the trousers, similarly to images c to e of participant C (Figure 5, image w–z).

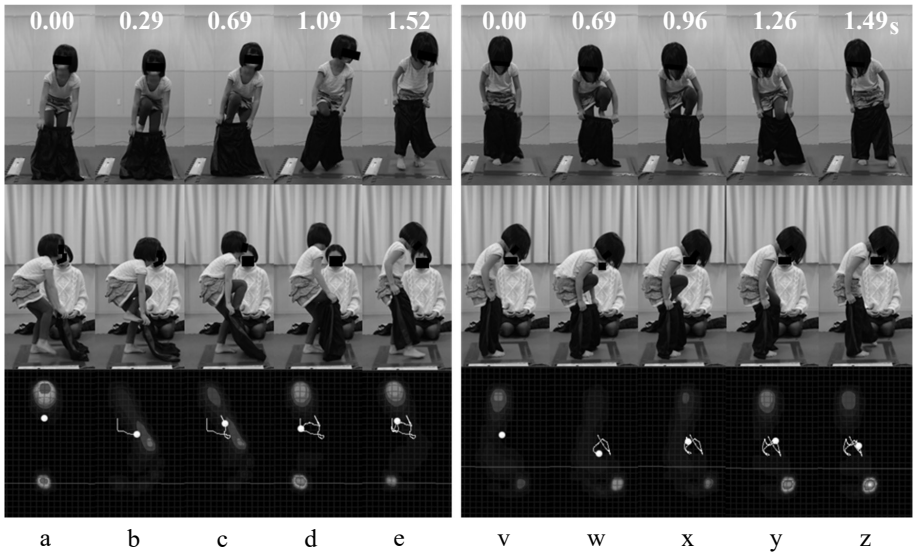

Figure 5 Motion images indicated the participant C of P2 and P4.

Table 3 Number and ratio by each type.

Age group	Type 1	Type 2	Type 3
4	8 (44)	2 (10)	2 (17)
5	8 (44)	8 (40)	3 (25)
6	2 (12)	10 (50)	7 (58)
Total	18 (36)	20 (40)	12 (24)

Column indicated the type of putting on trousers and line indicated age. Parentheses indicated the type of putting on trousers percentage of each age.

Table 4 Correlation between the type of putting on trousers and age and total time of the motion of putting on trousers.

	Age group	Total time
r	0.377	-0.376
p	0.003	0.001

Kendall rank correlation coefficient (*r*) and provability (*p*).

The foot pressure increased on the inside of the toe side and was indicated on the sole of the foot. Moreover, there was no deviation of the foot pressure distribution such as images w–z of participants A and B. The COP was displaced in the middle of the foot in each direction of AP and ML.

In single-leg standing (Task 1), each side time of participant C was 10.0 s, respectively. The position of the upper limbs of participant C was along the trunk. Moreover, participant C bent the trunk lateral slightly to the support leg side on each leg.

Mentioned above, participant C performed the motion with grasping of the waistline of the trousers near the support leg knee, and fixed the trousers and extended swing leg to fit the trousers in P2 and P4. The foot pressure of participant C more indicated outside and the sole of the foot than participant A and B. The COP displacement in the AP direction was more decreased than that of participant A and B. Participant C, who showed such motion characteristics was classified into Type 3. Other participants who performed similar motion characteristics on P2 or P4 were also classified as Type 3. In addition, no Type 3 participant performed with an imbalance of motion similar to that shown for Type 2. The motion characteristics of Type 3 were shown in Table 2.

Twelve participants showed these motion characteristics. Of these, one participant abducted their upper limbs to maintain balance while standing on a single leg (Task 1). The total times on a single leg of Type 3 participants were 16.4 s–20.0 s, with a median of 20.0 s.

Type classification agreement among all OTs

In Type 1, fourteen participants (78%) were classified by three OT and four (22%) by two OT. The four participants classified by the two OT were judged as Type 1 or 2. In Type 2, five participants (25%) were classified by three OT and fifteen (75%) by two OT. Of the fifteen participants classified by the two OT, nine were judged as Types 2 or 1, and six were judged as Type 2 or 3. In Type 3, all participants (100%) were classified by three OT. The concordance rate of the three OT was 62% and of two was 38% (W=0.876, p=0.000).

Difference between age and type of putting on trousers

All participants were classified into three types (Table 3). Fisher's exact test results were associated among age and type (p=0.020). The results showed that just as there is an order to age, there is also an order to type.

Relation between type of putting on trousers and analysis items

Correlation between type of putting on trousers and

Table 5 Correlation between the type of putting on trousers and analysis items of putting on trousers.

	Time	Path length	Path velocity	AP velocity	ML velocity	AP max	ML max
r	-0.186	-0.376	-0.130	-0.172	-0.001	-0.354	-0.180
p	ns	0.001	ns	ns	ns	0.001	ns

AP and ML were anterior and posterior direction, medial and lateral direction in displacement of COP. AP and ML max were AP maximum displacement, ML maximum displacement. Kendall rank correlation coefficient (*r*) and provability (*p*). The ns was no significant. Abbreviation in this as well as Table 6.

Table 6 Correlation between the type of putting on trousers and analysis item of single-leg standing.

	Time	Path length	Path velocity	AP velocity	ML velocity	AP max	ML max
r	0.392	-0.136	-0.450	-0.425	-0.368	-0.420	-0.430
p	0.001	ns	0.000	0.000	0.001	0.000	0.000

each parameter was shown in Tables 4–6. The type of putting on trousers was positively correlated with age and single-leg standing time. In the motion of putting on trousers, the type of putting on trousers negatively correlated with path length, AP maximum displacement, and total time. In addition, the type of putting on trousers negatively correlated with path velocity, the AP and ML direction velocity and maximum displacement of single-leg standing.

Discussion

The authors focused on the difference motion in the putting on trousers in a standing position in typically developing children aged 4–6 years old and their relation to balance ability. The motion of putting on trousers was divided into five phases. However, the relation between the motion of putting on trousers and the single-leg standing position required analysis of the phase in which the motion was performed with a single leg. Results showed, motion of the putting on trousers in a standing position was classification of into three types.

Classification of putting on trousers in a standing position

Based on the motion characteristics, three OTs classified the motion of putting on trousers of participants into three types. Type 1 motion characteristics were motion with slight trunk flexion and great hip and knee joints flexion. In addition, participants grasped the waistline of the trousers with one hand, or put their swing leg on the floor during motion, hooked their foot on the trousers and repeated the same procedure. Type 2 motion characteristics were the motion with participants grasping the waistline of the trousers in a higher position than the support leg knee, and fixing of the swing leg and pulling up of the waistline of the trousers to fit swing leg with both hands. Type 3 motion characteristics were the motion with participants flexing their trunk, grasping the waistline of the trousers near the support leg knee, and fixing the trousers and extending swing leg to fit the trousers. Moreover, the concordance rate of the three OTs was high for Types 1 and 3. The concordance rate of the two OTs was high for Type 2. These results suggested that Type 1 and Type 3 participants showed clear different motion characteristics. However, Type 2 participants showed that their motion characteristics were in the process of changing from Type 1 to Type 3.

As a result of comparing types and ages (Table 3) showed a significant difference between age and type of putting on trousers. Furthermore, positive correlation was found between type and age.

Therefore, these findings suggested that the three types reflect a developmental process. Kit et al[13] reported that children aged 3–5 years developed gross motor skills with age. Gallahue and Donnelly[14] presented that 3–5 years children were classified in a transitional phase from the initial to mature fundamental movement phase. In addition, the development of fundamental movement shifted to the maturity phase by child age of 6–7 years. Furthermore, child performance improved rapidly. Thus, Type 2 motion characteristics were in the transitional phase of the motion of putting on trousers in a standing position.

Relation between type of putting on trousers and each parameter

In single-leg standing, the single-leg standing time increased as the type changing from 1 to 3. The path velocity, AP and ML velocity and maximum displacement while single-leg standing decreased as the type changing from 1 to 3. Furthermore, the number of participants who maintained the single-leg standing balance without using upper limbs abduction increased as the type changing from 1 to 3. Ayres[11] reported that the single-leg standing time increased with age. Zumbrunn et al[15] reported that the path velocity, the AP and ML direction velocity and maximum displacement of the typically developing children standing on a single leg decreased with age. The anterior COP displacement while the typically developing children abducted the upper limbs horizontally in the double-leg standing position decreased concomitantly with increasing age[16]. These reports supported that our results of single-leg standing were involved in the maturation of the motion of putting on trousers in a standing position. Therefore, the maturity of single-leg standing was required for improved motion in wearing trousers with Type 2 motion characteristics.

For each parameter of the type classification, type of putting on trousers was positively correlated with age. The total time and path length while motion of putting on trousers decreased as the type changing from 1 to 3. Deschamps et al[17] reported that the total COP displacement in typically developing children decreased with age while changing from the double-leg standing position to the single-leg standing position. The motion of putting on trousers in a standing position included the change in posture from the double-leg standing position to a single-leg standing position, as well as coordinated the trunk, upper and lower limbs motions. Thus, the motion of putting on trousers in a standing position required higher posture stability than only single-leg standing. Therefore, the total time and path length of each type was refracted in the stability and maturity of the motion of putting on trousers in a standing position. These findings suggested that relation between age and the maturity of the motion of putting on trousers in a standing position was required to have single-leg standing balance and trunk, upper, and lower limbs coordination.

Furthermore, participants performed the motion with trunk flexion as the type changing from 2 to 3. The center of gravity (COG) was displaced in the anterior direction because the putting on trousers in a standing position was done by grasping the trousers. The trunk flexion caused COG anterior displacement. When changes in the COG occur, the COP displacement will always be somewhat greater than the COG displacement to maintain balance[18]. In other words, putting on trousers in a standing position was the motion which required control of the COP in the AP direction. For this study, the maximum displacement in AP direction while putting on trousers decreased as the type changing from 1 to 3. These findings speculated that the trunk flexion and control of COP in the AP direction during putting on trousers were related with the maturity of the motion of putting on trousers in a standing position.

OT uses play to bring out the activeness of children who have difficulty changing trousers. These activenesses consist of single-leg standing and coordinate motions of the trunk, upper and lower limbs. The finding revealed that putting on trousers in a standing position in each type included to differences in the motor elements of play.

Conclusion

The motions of putting on trousers in a standing position for typically developing children aged 4–6 years were classified into three types. As the type changing, there was a difference in the age of the children. Moreover, the difference was the motion by which the participants flexed their trunk, grasped the waistline of the trousers near the support leg knee, and fixed the trousers and extended the swing leg to fit the trousers as the type changing. These motion characteristics decreased the total time, path length, and AP maximum displacement while putting on trousers in a standing position. In single-leg standing, the total time increased, and the path velocity, the AP and ML direction velocity and maximum displacement decreased as the type changing. These results suggested that differences in putting on trousers in a standing position for typically developing children aged 4–6 years exhibit three types. The types were related with standing on a single leg. Furthermore, these results speculated that the motion characteristics and the control of COP in the AP direction during the putting on trousers were related to the maturation of the motion of the putting on trousers in a standing position in typically developing 4–6-years-old children.

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Conflict of interest

The authors declare that they have no conflict of interest.

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要　　旨

この研究の目的は，4-6 歳の定型発達児の立位ズボン履き動作と片脚立位との関係を明らかにすることであった．

対象は，男児 28 名と女児 22 名の定型発達児（4.5 ± 0.4 歳，5.5 ± 0.3 歳，6.6 ± 0.3 歳）であった．課題は，10 秒間の片脚立位と立位でのズボン履きであった．

結果，動作特徴に基づいて，ズボン履き動作は 3 タイプに分類された．タイプ 1 と 2 と比較すると，タイプ 3 は，対象者が体幹を屈曲し，ズボンのウエストラインを支持脚の膝付近で把持し，固定したズボンに合わせて遊脚を伸展したことを示した．これらの動作特徴により，立位ズボン履き動作の所要時間，総軌跡長，前後最大変位は短くなった．そして，タイプが 1 から 2 と 3 へ変わると年齢は増加した．片脚立位の際，タイプが 1 から 2 と 3 へ変わると片脚立位時間は増加し，片脚立位の際の速度と最大変位は減少した．

以上から，4-6 歳の定型発達児における立位ズボン履き動作の 3 つのタイプは，年齢とともに成熟し，片脚立位と関連することを示唆した．

キーワード：荷重中心点，着替え，ズボン履き，定型発達児