J. Phys. Ther. Sci. 29: 123–127, 2017

The Journal of Physical Therapy Science

Original Article

A comparison of the balance and gait function between children with Down syndrome and typically developing children

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Abstract. [Purpose] The purpose of this study was to compare the balance and gait functions of children with Down syndrome and typically developing children according to age. [Subjects and Methods] The subjects were 16 children with Down syndrome and 20 children with typical development. The one leg standing test, Romberg's test (open eyes/closed eyes), sharpened Romberg's (open eyes/closed eyes), functional reaching test and GAITRite were used for this study in order to measure the children's balance and gait function. [Results] The results of this study showed that static-dynamic balance ability, spatio-temporal gait parameters and quality of life were statistically and significantly different in Down syndrome children compared to typically developing children. [Conclusion] These results suggest that the balance and gait ability of typically developing children improves during growth, whereas those of children with Down syndrome remain low despite independent gait. Therefore, constant therapeutic intervention for balance and gait function is necessary after independent gait development in Down syndrome children.
Key words: Down syndrome, Balance, Gait

(This article was submitted Aug. 31, 2016, and was accepted Oct. 17, 2016)

INTRODUCTION

Down syndrome is caused by an abnormal extra presence of the 21st chromosome[1, 2)]. Due to the resulting nonhereditary mental retardation, several problems arise such as developmental delay, hearing problems, vision problems and respiratory dysfunctions[1–3)]. In particular, disabilities related to motor function are extensive, for example abnormal gait patterns and postural control, dilatory response to environment alteration, lack of coordination, and concurrent contraction of agonists and antagonists[4)]. Juvenile motor development is delayed because muscle activation patterns are unstable and not well-organized and thus, motor dysfunction leads to muscle dystonia[5, 6)].

Motor dysfunction in childhood leads to limited physical activity and lack of activity experience, in addition to developmental delay of the senses and perception, concept formation of movement, and social ability. Equilibrium is an ability that keeps the center of gravity within the base of support with a limited amount of sway, thus it is essential for postural control and activity[7)]. The clinical ability to control equilibrium is crucial for children. Above all, postural balance control of standing and sitting is important for the improvement of life quality through activities of daily living[8)]. Balance is one of the major factors that affect the safety and independence skills of Down syndrome children, and is the hardest function to acquire. The gross motor skills of Down syndrome children are consistently low compared to those of normal children, and balance shows the largest difference. Gait is an important indicator of motor development in humans. It can affect cognition, sociality, and complicated motor abilities such as running and jumping[9)]. Independent walking in the development process of

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children depends on appropriate balance and effective driving force. When the non-supporting foot uses most of its power as the driving force, it is important that the supporting foot maintains the balance in early independent gait[10].

Compared to typically developing children, Down syndrome children experience a delay of 12 to 18 months for independent gait and approximately 80% of Down syndrome patients experience gait malfunctions due to insufficient strength[9]. As a result, there is a difference in their gait patterns compared to typically developing children. Especially, the biological characteristics of Down syndrome associated with muscle hypotonia, excessive ligament laxity, postural instability, and lack of balance have a negative impact on the normal development of gait[1, 5, 6].

Balance and gait play a critical role in activities of daily living for humans, and can be affected by interior or exterior factors as the subject becomes older[11]. Movement is limited due to the dysfunction of balance and gait. Additionally, life quality and participation in daily living are affected[12].

Therefore, in this study, we measured the balance ability and gait function of Down syndrome children and typically developing children to compare and analyze the two groups. The collected information provides the basic data necessary to develop an intervention program for the improvement of balance and gait function. In addition, this study evaluated and established goals that can be helpful for therapists, Down syndrome children, and their parents.

SUBJECTS AND METHODS

The subjects were 16 Down syndrome children and 20 children with typical development, for a total of 36 children. Participants were divided according to age into 2 groups: children before school-age were 4–7 years old and school-aged children were 8–12 years old. The present study was approved by the Sahmyook University Institutional Review Board and the objectives of the study as well as the requirements were explained to the subjects. All participants provided written parental consent, in accordance with the ethical principles of the Declaration of Helsinki.

The inclusion criteria were as follows for Down syndrome children: (1) ability to walk 20 meters without assistance, (2) ability to comply with researchers' and guardians' instructions, and (3) permission from parents for the study. The exclusion criteria were as follows: (1) visual or auditory problems, and (2) a major history of disease or surgery.

The inclusion criteria were as follows for typically developing children: (1) ability to comply with researchers' and guardians' instructions, and (2) permission from the parents for the study. The exclusion criteria were as follows: (1) visual or auditory problems, and (2) musculoskeletal disease or taking medicine related to musculoskeletal illness within the last 6 months. Children with a history of surgery were also excluded.

Static balance ability was measured using the One Leg Standing Test (OLST), Romberg's Test (RT) and the Sharpened Romberg's Test (SRT). The OLST was used to assess static balance. Participants were instructed to keep their balance on the non-dominant leg with eyes open. The elapsed time before the contra-lateral foot touched the ground was measured in seconds using a stopwatch[13]. Romberg's test is a static balance test. Subjects were required to stand with their feet together, eyes open or closed, with hands by their sides for a period of time, usually a minute. The sharpened Romberg's test was conducted with the dominant foot positioned behind the non-dominant foot to form a straight line with the toes behind the heel and both arms crossed in a natural pose. The functional reaching test (FRT) is a dynamic balance test. Subjects were asked to stand 10 cm from the wall so that their shoulders were perpendicular to the reach measurement device. Subjects extended their arms horizontally and placed a closed first against the sliding handle[14].

Gait function was measured using a GAITRite system (CIR Systems Inc., Havertown, PA, USA). The GAITRite system was used to measure spatiotemporal parameters, including gait velocity, cadence, step length, stride length and step width. The subjects were asked to walk at a comfortable speed, without the use of an assistive device, along a 10-m hallway[15].

All statistical analyses were performed using SPSS, version 19.0. The general characteristics are presented as frequencies and percentages, with average and standard deviations also provided. The independent t-test was used for the analysis of changes in dependent variables between groups. The significance threshold was set to $p<0.05$.

RESULTS

The demographic characteristics of the subjects are shown in Table 1. Thirty-six subjects participated in this study, sixteen males and twenty females. Subjects in the Down syndrome children group and the typically developing children group were similar in terms of age, height, and weight. No significant differences between the general characteristics of the two groups were detected at recruitment.

The one leg standing test, Romberg's test, sharpened Romberg's test of static balance and FRT of dynamic balance showed significant differences in the two groups (Table 2). The velocity, cadence of temporal gait parameters and step length, stride length, and step width of spatial gait parameters also showed significant differences in the two groups. The typically developing children group showed significant differences in Romberg's test with closed eyes, sharpened Romberg's with closed eyes, FRT, step length and stride length during growth. The Down syndrome child group only showed significant differences in cadence during growth.

Table 1. Characteristics of the participants (N=36)

		Down syndrome children (n=16)	Typically developing children (n=20)
Gender Male/Female (%)	Total	7 (19.4)/9 (25.0)	9 (25.0)/11 (30.6)
	Before school-age	3 (8.3)/6 (16.7)	4 (11.1)/5 (13.9)
	School-aged children	4 (11.1)/3 (8.3)	5 (13.9)/6 (16.7)
Age (yrs)	Total	6.8 (1.8)	8.0 (2.4)
	Before school-age	5.4 (1.0)	5.8 (1.2)
	School-aged children	8.4 (0.8)	9.7 (1.3)
Height (cm)	Total	90.6 (26.5)	119.5 (20.3)
	Before school-age	79.2 (30.0)	101.6 (10.7)
	School-aged children	105.3 (10.7)	134.2 (13.0)
Weight (kg)	Total	15.4 (6.3)	26.3 (11.1)
	Before school-age	11.6 (4.5)	17.1 (4.4)
	School-aged children	20.1 (4.8)	33.8 (9.0)

n (%) or mean (SD); Total: children aged 4 to 12; before school-age: 4–7 years old; school-aged children: 8–12 years old

DISCUSSION

Ability to keep the center of gravity within the base of support and balance is critical for ADL, mobility and performance for children, and thus is an essential requisite for all kinds of exercise. Therefore, functional enhancement with the improvement of balance performance is expected[16].

This study was performed to compare static balance (one leg standing test, Romberg's test and sharpened Romberg's) and dynamic balance (functional reaching test) between Down syndrome children and typically developing children. In this study, balance ability analysis was performed by dividing the subjects into a preschool age group and a school age group as the balance ability changes during growth[11]. The Down syndrome children had significant differences in all areas of balance ability in comparison with typically developing children ($p<0.05$). Typically developing children showed higher balance ability than the Down syndrome children. This corresponds with the following previous study results: the static-dynamic balance of Down syndrome children showed more differences than other motor skills compared to typically developing children and Down syndrome children lack static balance ability[17]. The reason for this is that their muscle reaction velocity is significantly slower compared to their peers, and there is much difficulty with vision, motor control, and agility[1, 3–6].

The one leg standing test for Down syndrome children (0.63 second) lasted for a shorter period than for typically developing children (45.54 seconds). This is because the proprioception sense in Down syndrome children is decreased and they tend to have a wider basal surface due to the low stability from the narrow basal surface.

Typically developing children of all ages maintained their balance with eyes closed for a shorter period than with eyes open in the Romberg's and Sharpened Romberg's tests. The Down syndrome children also had similar results. This indicates that postural disturbance is larger when standing with eyes closed, and decreases when visual feedback about the position is provided, increasing visual dependence[18].

In the Romberg's test (RT) (eyes open, EO: 58.65 sec, eyes closed, EC: 52.95 sec), normal children of all ages maintained their balance for a longer period of time than in the Sharpened Romberg's test (SRT) (eyes open: 50.35 sec, eyes closed: 40.35 sec), showing that SRT requires higher balance ability than RT. Down syndrome children of all ages showed a markedly low balance ability in SRT (EC) compared to typically developing children of all ages. This is because SRT requires a higher level of balance ability than RT. SRT (EC), even with visual feedback, is a difficult task for Down syndrome children with low balance ability (0.00 sec).

When comparing the balance ability of typically developing children of preschool age and school age, there was a significant difference in the Romberg's test (eyes closed), Sharpened Romberg's test (eyes closed) and functional reaching test ($p<0.05$). These results show that the balance ability of typically developing children improves with growth. However, when comparing the balance ability of Down syndrome children of preschool age and school age, there was no significant difference in all 6 fields, and both groups displayed low balance ability. These results show that the balance ability of typically developing children improves with growth, but that of Down syndrome children remains low despite the acquisition of independent gait. Therefore, constant therapeutic intervention for balance after independent gait achievement is necessary.

Gait is the most important activity among human movement as it is the basis of all movements in daily life, and normal gait development in childhood is significant in the aspect of motor development. In particular, gait in Down syndrome children is a necessary physical activity to experience the surrounding environment and improve health[19]. In this study, gait ability analysis was conducted using GAITRite for Down syndrome children and typically developing children. The gait

Table 2. Comparison of the balance and gait function (N=36)

		Down syndrome children (n=16)	Typically developing children (n=20)
Balance function			
OLST (s)	Total	0.6 (1.1)	45.5 (17.1)‡
	Before school-age	0.2 (0.5)	38.1 (20.8)‡
	School-aged children	1.3 (1.4)	51.6 (10.8)‡
RT(EO) (s)	Total	0.6 (2.0)	58.7 (6.0)‡
	Before school-age	0.1 (0.3)	57.0 (9.0)‡
	School-aged children	1.1 (3.0)	60.0 (0.0)‡
RT(EC) (s)	Total	0.6 (2.3)	53.0 (13.5)‡
	Before school-age	0.0 (0.0)	44.6 (17.0)‡
	School-aged children	1.3 (3.4)	59.8 (0.60)*, ‡
SRT(EO) (s)	Total	0.5 (2.0)	50.4 (14.2)‡
	Before school-age	0.0 (0.0)	44.4 (16.1)‡
	School-aged children	1.1 (3.0)	55.2 (10.8)‡
SRT(EC) (s)	Total	0.0 (0.0)	40.4 (21.8)‡
	Before school-age	0.0 (0.0)	26.4 (19.4)‡
	School-aged children	0.0 (0.0)	51.7 (16.7)**, ‡
FRT (cm)	Total	12.0 (3. 5)	25.2 (6.4)‡
	Before school-age	10.9 (2.5)	20.9 (5.6)‡
	School-aged children	13.3 (4.2)	28.8 (4.8)**, ‡
Gait function			
Velocity (cm/s)	Total	85.8 (16.0)	103.23 (25.89)†
	Before school-age	90.1 (11.9)	91.43 (19.06)
	School-aged children	80.3 (19.8)	112.89 (27.48)†
Cadence (steps/mim)	Total	154.8 (30.1)	131.6 (18.2)‡
	Before school-age	171.2 (28.3)	137.7 (16.7)‡
	School-aged children	133.7 (16.7)**	126.5 (18.5)
Step length (cm)	Total	33.6 (6.7)	47.5 (10.9)‡
	Before school-age	31.8 (3.7)	40.1 (7.1)‡
	School-aged children	35.9 (9.1)	53.6 (9.8)**, ‡
Stride length (cm)	Total	67.4 (12.1)	95.1 (22.4)‡
	Before school-age	63.8 (5.9)	80.5 (14.4)‡
	School-aged children	72.1 (16.7)	107.1 (21.0)**, ‡
Step width (cm)	Total	10.9 (2.7)	8.8 (2.1)‡
	Before school-age	11.2 (2.7)	8.4 (1.7)†
	School-aged children	10.6 (2.5)	9.1 (2.4)

Values are means (SD). Total: children aged 4 to 12; Before school-age: 4–7 years old; School-aged children: 8–12 years old; OLST: one leg standing test; RT: Romberg test; SRT: Sharpened Romberg test; FRT: functional reaching test; EO: Eyes Open; EC: Eyes Closed; *p<0.05 compared with the Before school-age and School-aged children; **p<0.01 compared with the Before school-age and School-aged children; † p<0.05 from mean between the two groups; ‡ p<0.01 from mean between the two groups

analysis was performed by dividing the subjects into a preschool age group and a school age group as the gait pattern changes during growth[11].

In this study, the Down syndrome children had a shorter stride and stride length and a wider stride interval among the spatial gait variables. The abnormal splayfooted gait with decreased stride width and wide stride interval is because of instability due to weaker lower extremity strength and a lower balance function[20]. Stride length is related to the leg length. Down syndrome causes physical imbalance and growth delays due to nutritional imbalance and movement restrictions. The stride length of Down syndrome children is 45.94 cm compared to 58.30 cm for typically developing children, indicating a short stride length for Down syndrome children. In the present study, the results showed that the legs of typically developing children grew longer as they approached school age, resulting in increased stride length (p<0.05). Stride and stride length

are also related to a child's balance ability in addition to leg length. Down syndrome children have less balance compared to typically developing children[21] so they are unable to position their feet far apart between the terminal swing phase and the initial stance phase and instead position them close together, resulting in a shorter stride and stride length. Short stride and stride length result in slow gait velocity and high cadence. The pre-school aged Down syndrome children showed significant differences in step width (11.17 cm) in comparison with typically developing children (8.38 cm) ($p<0.05$). This is because Down syndrome children tend to have a wider basal surface due to low stability with a narrow basal surface[21].

Most of the parents of the Down syndrome children do not regard physical therapy intervention as important after the children achieve independent gait. According to this study result, however, Down syndrome children consistently show abnormal gait patterns compared to typically developing children, and the balance ability is markedly decreased as well. The reduced balance and gait ability limits their ability to handle sudden environmental changes and participation in daily life. As mentioned previously, continuous physical therapy intervention for balance ability improvement is necessary even after independent gait, so the children can increase their participation in daily life and handle sudden changes in their environment.

The results of the gait variables proposed in this study reveal the extent of the abnormal gait in Down syndrome children, and can be used as basic data in developing gait intervention programs and setting treatment goals.

ACKNOWLEDGEMENT

This paper was supported by the Health Sciences for Specialization Project Fund of the Sahmyook University in 2016.

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