A comparison of ankle function between adults with and without Down syndrome

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Objective: The purpose of this study was to compare ankle function between adults with and without Down syndrome (DS).

Design: Cross-sectional study.

Methods: Ten adults with DS and 18 without participated in this study and underwent manual muscle test (MMT), range of motion (ROM) assessment, star excursion balance test (SEBT), and functional movement screen (FMS). The tests were demonstrated to increase their accuracy and the actual measurements were assessed after one or two demonstrations. To minimize the standby time and fatigue, the travelled distance and measuring order were adjusted. To remove the influence of shoes on the measurements, the shoes were taken off and only socks were worn.

Results: Dorsal and plantar flexion MMTs of both ankles were significantly weaker and plantar flexion ROM of both ankles were significantly lower in adults with DS compared with those without ($p < 0.05$). However, dorsal flexion ROM of both ankles were not significantly different between them. There were significant differences in distances measured in all the directions (anterior, anterolateral, lateral, posterolateral, posterior, posteromedial, medial, and anteromedial directions) of SEBT ($p < 0.05$). Significant differences were also demonstrated in the scores of hurdle step, inline lunge, shoulder mobility, and rotary stability among the seven items of FMS ($p < 0.05$).

Conclusions: To enhance the dynamic stability of adults with DS, it is necessary to improve ankle stability by strengthening the ankle dorsal and plantar flexors.

Key Words: Ankle, Down syndrome, Functional movement screen, Star excursion balance test

Introduction

Down syndrome (DS) is a chromosomal abnormality and can result in significant defects in cognitive and motor development [1]. Particularly, motor disturbances, such as abnormal gait and posture adjustments, slow responses to environmental changes, incoordination, and co-contraction of agonistic and antagonistic muscles have been demonstrated [2-4]. Such motor disturbances caused by DS lead to limited physical activities and exercise experience, and, thereby,

cause a delay in sensory development, concepts of movement, and social development [5-8].

Balance is the ability to sustain the body's center of gravity within the base of support during minimal motion, and is a fundamental element of posture, gait, and exercise. Balance is adjusted following the integration of the afferent information sent from the somatosensory, visual, and vestibular systems in the central nervous system, which induces reflex control of the eyes and extremities [9]. Therefore, balance greatly influences independent living and safety of pa-

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tients with DS; it is the motor function that is very difficult for these individuals to acquire [10-12].

Balance is an important factor for the activities of daily living. In cases of balance-related disabilities, movement can be limited, which may have a negative impact on not only the participation in activities of daily living but also the quality of life [13,14]. The stability of the ankle joint is crucial to balance [15,16]. Although DS is known to result in congenitally poor ankle stability [17,18], there are no studies that have precisely investigated this topic. The objectives of the present study were to conduct tests of ankle stability, such as the star excursion balance test (SEBT), functional movement screen (FMS), manual muscle test (MMT), and range of motion (ROM) assessment between adults with DS and those without to identify any significant differences, and use the results to propose guidelines of strengthening the muscles that will allow adults with DS to actively participate in their daily lives and social activities. Furthermore, another objective was to construct a database that can be used as the foundation for developing tests to evaluate the functional movements in adults with DS.

Methods

Participants

Twenty-eight participants were enrolled, which included 10 patients (aged 21-31 years) with DS and 18 students (aged 20-24 years) without DS from a university in Seoul. In the process of selecting the subjects, those with hearing and visual problems, musculoskeletal problems, ankle sprain, lower back pain, and history of major surgeries and diseases were excluded.

Procedures

MMT, ROM, SEBT, and FMS were conducted in all participants. Through survey and measurements, the general characteristics, such as sex, age, weight, and height were recorded. After the details of the study were explained, all participants provided their informed consent. The tests were demonstrated to increase their accuracy and the actual measurements were recorded after one or two demonstrations.

To minimize the standby time and fatigue, the measuring order and distance travelled were flexibly adjusted. To remove the influence of shoes on the measurements, they were taken off and only socks were worn.

Measurement tools

MMT

MMT is a test conducted to evaluate an individual's maximum muscular strength and has been the standard for measuring muscular strength of the overall body for a long time [19]. The contractile forces of the muscles involved are strongly related to the MMT score [20]. The extensor muscles of the ankle play an important role in gait [21].

ROM

The double-armed universal goniometer was used to measure the active ROM of the ankle joint. The basic posture for this set of tests was as follows: the participant was in the supine position, with the fixed arm positioned with the neutral position of the feet and the working arm positioned parallel to the line connecting the outer side of the heel and the end of the 5th toe.

SEBT

SEBT is a test conducted to evaluate the balance of the subjects by measuring the raised distance while having the subjects bear their body weight onto one leg and raise the other leg in 8 directions [22] (Figure 1). While this test is conducted, the body, the leg bearing the weight, and the nerves involved must be efficient to maintain movement and balance over the body's base of support [23]. SEBT has been clinically used to accomplish the purpose of research. Particularly, it is a very reliable and valid tool for measuring the dynamic balance ability in people with chronic ankle instability. To conduct SEBT, lines were drawn in 8 directions (anterior direction, anterolateral direction, lateral direction, posterolateral direction, posterior direction, posteromedial direction, medial direction, and anteromedial direction), and the participant stood at the center of the lines on one leg and

Figure 1. Star excursion balance test.

raised the other leg as much as possible towards the lines in the clockwise fashion starting from the anterior direction [22].

FMS

FMS is a test conducted to evaluate the seven movements required for balance between mobility and stability (Figure 2). The seven movements are deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and quadruped rotary stability. In this test, a score ranging from 0 to 3 is assigned for each movement. The right side and left side are separately tested, and the lower score between the two is used as the final score. In FMS, all the functional disorders and causes of pain can be revealed through the seven basic movements. In case any pain is felt during the test, the test is stopped until it is resumed in the presence of a medical team. Additionally, it is the test that determines the time for patients undergoing rehabilitation to return to their daily lives [24,25].

Statistical analysis

IBM SPSS Statistics ver. 20.0 (IBM Co., Armonk, NY, USA) was used to analyze the descriptive statistics and general characteristics, and the independent t-test was used to compare the data of the tests. The statistical significance level was set at $\alpha = 0.05$.

Results

General characteristics of the participants

The general characteristics of the participants are shown in Table 1. Of the 10 adults with DS, 3 were men (30.0%) and 7 women (70.0%), and of the 18 adults without DS, 11 were men (61.1%) and 7 women (38.9%). The mean age of the adults with DS was 25.00 ± 2.944 years whereas that of adults without DS was 21.44 ± 1.580 years. The mean height of the adults with DS was 153.40 ± 7.675 cm, whereas that of the adults without DS was 170.52 ± 8.139 cm. The mean weight of the adults with DS was 65.70 ± 7.675 kg, whereas that of

Figure 2. Functional movement screen. (A) Deep squat. (B) Hurdle step. (C) Inline lunge. (D) Shoulder mobility. (E) Active straight leg raise. (F) Trunk stability push-up. (G) Quadruped rotary stability.

Table 1. General characteristics of subjects (N=28)

Characteristic	Adults with DS (n=10)	Adults without DS (n=18)
Male/female	3 (30.0)/7 (70.0)	11 (61.1)/7 (38.9)
Age (yr)	25.00 (2.944)	21.44 (1.580)
Height (cm)	153.40 (7.675)	170.52 (8.139)
Weight (kg)	65.70 (7.675)	64.50 (11.142)

Values are presented as n (%) or mean (SD).

DS: Down syndrome.

Table 2. Results of the MMTs (N=28)

Variable	Adults with DS (n=10)	Adults without DS (n=18)	t (p)
RD-MMT (kg)	4.15 (3.097)	19.36 (3.982)	10.424 (<0.001)
RP-MMT (kg)	3.42 (2.140)	25.92 (12.546)	5.581 (<0.001)
LD-MMT (kg)	4.36 (3.610)	19.69 (7.659)	5.938 (<0.001)
LP-MMT (kg)	3.84 (2.308)	24.98 (13.079)	5.027 (<0.001)

Values are presented as mean (SD).

MMT: manual muscle test, DS: Down syndrome, RD-MMT: right dorsal MMT, RP-MMT: right plantar MMT, LD-MMT: left dorsal MMT, LP-MMT: left plantar MMT.

the adults without DS was 64.50±11.142 kg.

MMT

The results of ankle MMT are shown in Table 2. Right dorsal (RD)-MMT was 4.15±3.097 kg in the adults with DS and 19.36±3.982 kg in those without ($p<0.05$). Right plantar (RP)-MMT was 3.42±2.140 kg in the adults with DS and 25.92±12.546 kg in those without ($p<0.05$). Left dorsal (LD)-MMT was 4.36±3.610 kg in the adults with DS and 19.69±7.659 kg in those without ($p<0.05$). Left plantar (LP)-MMT was 3.84±2.308 kg in the adults with DS and 24.98±13.079 kg in those without ($p<0.05$).

ROM

The ROM results of the ankle are demonstrated in Table 3. Right dorsiflexion ROM (RDFROM) was 36.32°±6.425° in the adults with DS and 38.02°±8.840° in those without, which was not significant ($p>0.05$). Right plantar flexion ROM (RPFROM) was 22.36°±6.806° in the adults with DS and 34.14°±4.637° in those without ($p<0.05$). Left dorsiflexion ROM (LDFROM) was 31.86°±8.870° in the adults with DS and 38.41°±6.580° in those without; the difference was not statistically significant ($p>0.05$). Left plantar flexion ROM (LPFROM) was 25.14°±6.054° in the adults with DS and 37.43°±4.983° in those without ($p<0.05$).

Table 3. Results of ROM assessments (N=28)

Variable	Adults with DS (n=10)	Adults without DS (n=18)	t (p)
RDFROM (°)	36.32 (6.425)	38.02 (8.840)	0.534 (0.598)
RPFROM (°)	22.36 (6.806)	34.14 (4.637)	5.444 (<0.001)
LDFROM (°)	31.86 (8.870)	38.41 (6.580)	2.229 (0.350)
LPFROM (°)	25.14 (6.054)	37.43 (4.983)	5.796 (<0.001)

Values are presented as mean (SD).

ROM: range of motion, DS: Down syndrome, RDFROM: right dorsiflexion ROM, RPFROM: right plantarflexion ROM, LDFROM: left dorsiflexion ROM, LPFROM: left plantarflexion ROM.

Table 4. Results of the SEBT (N=28)

Variable	Adults with DS (n=10)	Adults without DS (n=18)	t (p)
1RSEBT (cm)	24.60 (11.157)	59.11 (7.584)	9.741 (<0.001)
2RSEBT (cm)	32.40 (13.882)	64.22 (7.727)	7.846 (<0.001)
3RSEBT (cm)	38.40 (16.735)	70.56 (8.111)	6.892 (<0.001)
4RSEBT (cm)	39.30 (18.500)	75.00 (9.899)	6.700 (<0.001)
5RSEBT (cm)	32.40 (14.781)	74.22 (8.592)	9.526 (<0.001)
6RSEBT (cm)	20.80 (19.257)	62.44 (9.978)	7.591 (<0.001)
7RSEBT (cm)	18.30 (10.584)	43.28 (10.676)	5.950 (<0.001)
8RSEBT (cm)	24.20 (12.977)	49.00 (9.337)	5.856 (<0.001)
1LSEBT (cm)	22.90 (12.723)	59.67 (8.239)	9.303 (<0.001)
2LSEBT (cm)	32.20 (13.481)	65.00 (7.754)	8.226 (<0.001)
3LSEBT (cm)	32.20 (15.720)	71.72 (9.112)	8.367 (<0.001)
4LSEBT (cm)	32.00 (15.463)	73.89 (10.781)	8.429 (<0.001)
5LSEBT (cm)	30.50 (15.615)	73.44 (9.395)	9.134 (<0.001)
6LSEBT (cm)	7.80 (18.725)	63.27 (10.250)	10.091 (<0.001)
7LSEBT (cm)	19.20 (12.934)	43.33 (10.550)	5.042 (<0.001)
8LSEBT (cm)	24.00 (14.205)	49.39 (7.868)	6.129 (<0.001)

Values are presented as mean (SD).

SEBT: star excursion balance test, DS: Down syndrome, 1RSEBT: right foot towards anterior, 2RSEBT: right foot towards anterolateral, 3RSEBT: right foot towards lateral, 4RSEBT: right foot towards posterolateral, 5RSEBT: right foot towards posterior, 6RSEBT: right foot towards posteromedial, 7RSEBT: right foot towards medial, 8RSEBT: right foot towards anteromedial, 1LSEBT: left foot towards anterior, 2LSEBT: left foot towards anterolateral, 3LSEBT: left foot towards lateral, 4LSEBT: left foot towards posterolateral, 5LSEBT: left foot towards posterior, 6LSEBT: left foot towards posteromedial, 7LSEBT: left foot towards medial, 8LSEBT: left foot towards anteromedial.

SEBT

SEBT results are shown in Table 4. Right foot towards the anterior direction on the SEBT (1RSEBT) was 24.60±11.157 cm in the adults with DS and 59.11±7.584 cm in those without ($p<0.05$). Right foot towards the anterolateral direction (2RSEBT) was 32.40±13.882 cm in the adults with DS and 64.22±7.727 cm in those without ($p<0.05$). Right

foot towards the lateral direction (3RSEBT) was 38.40 ± 16.735 cm in the adults with DS and 70.56 ± 8.111 cm in those without ($p < 0.05$). Right foot towards the posterolateral direction (4RSEBT) was 39.30 ± 18.500 cm in the adults with DS and 75.00 ± 9.899 cm in those without ($p < 0.05$). Right foot towards the posterior direction (5RSEBT) was 32.40 ± 14.781 cm in the adults with DS and 74.22 ± 8.592 cm in those without ($p < 0.05$). The right foot towards the posteromedial direction (6RSEBT) was 20.80 ± 19.257 cm for the adults with DS and 62.44 ± 9.978 cm for the normal adults, and, therefore, a significant difference was shown ($p < 0.05$). The right foot towards the medial direction (7RSEBT) was 18.30 ± 10.584 cm for the adults with DS and 43.28 ± 10.676 cm for the normal adults, and, therefore, a significant difference was shown ($p < 0.05$). The right foot towards the anteromedial direction (8RSEBT) was 24.20 ± 12.977 cm in the adults with DS and 49.00 ± 9.337 cm in those without ($p < 0.05$). The left foot towards the anterior direction (1LSEBT) was 22.90 ± 12.723 cm in the adults with DS and 59.67 ± 8.239 cm in those without ($p < 0.05$). Left foot towards the anterolateral direction (2LSEBT) was 32.20 ± 13.481 cm in the adults with DS and 65.00 ± 7.754 cm in those without ($p < 0.05$). Left foot towards the lateral direction (3LSEBT) was 32.20 ± 15.720 cm in the adults with DS and 71.72 ± 9.112 cm in those without ($p < 0.05$). Left foot towards the posterolateral direction (4LSEBT) was 32.00 ± 15.463 cm in the adults with DS and 73.89 ± 10.781 cm in those without ($p < 0.05$). Left foot towards the posterior direction (5LSEBT) was 30.50 ± 15.615 cm in the adults with

DS and 73.44 ± 9.395 cm in those without ($p < 0.05$). Left foot towards the posteromedial direction (6LSEBT) was 7.80 ± 18.725 cm in the adults with DS and 63.27 ± 10.250 cm in those without ($p < 0.05$). Left foot towards the medial direction (7LSEBT) was 19.20 ± 12.934 cm in the adults with DS and 43.33 ± 10.550 cm in those without ($p < 0.05$). Left foot towards the anteromedial direction (8LSEBT) was 24.00 ± 14.205 cm in the adults with DS and 49.39 ± 7.868 cm in those without ($p < 0.05$).

FMS

The results of FMS testing are shown in Table 5. The FMS score for the deep squat (FMS1) was 2.00 ± 0.943 in the adults with DS and 2.61 ± 0.608 in those without ($p > 0.05$). The FMS score for the hurdle step (FMS2) was 1.30 ± 0.483 in the adults with DS and 2.67 ± 0.485 in those without ($p < 0.05$). The FMS score for the inline lunge (FMS3) was 1.10 ± 0.568 in the adults with DS and 2.83 ± 0.383 in those without ($p < 0.05$). The FMS score for shoulder mobility (FMS4) was 1.50 ± 0.527 in the adults with DS and 2.50 ± 0.514 in those without ($p < 0.05$). The FMS score for the active straight leg raise (FMS5) was 2.80 ± 0.422 in the adults with DS and 3.00 ± 0.000 in those without ($p > 0.05$). The FMS score for trunk stability push-up (FMS6) was 1.40 ± 0.699 in the adults with DS and 2.33 ± 0.970 in those without ($p > 0.05$). The FMS score for quadruped rotary stability (FMS7) was 1.30 ± 0.483 in the adults with DS and 1.94 ± 0.236 in those without ($p < 0.05$). The overall FMS score was 11.40 ± 2.503 in the adults with DS and 17.89 ± 1.605 in those without ($p < 0.05$).

Discussion

Although there is general awareness that adults with DS have insufficient ankle stability, no research or study has focused on the ankle stability in them to calculate the precise results of tests. Therefore, we chose adults with and without DS as the subjects, compared the significant differences in ankle stability between them, and calculated the results. Based on the significant differences ($p < 0.05$) shown in the RPFROM, LPFROM, right dorsal flexor MMT, right plantar flexion MMT, left dorsal flexion MMT, and left plantar flexion MMT between the participants, we were able to quantitatively establish that the adults with DS demonstrated severe muscle weakness in comparison to those without DS. Based on the significant differences ($p < 0.05$) shown in the SEBT tests, we were able to confirm that the adults

Table 5. Results of FMS (N=28)

Variables	Adults with DS (n=10)	Adults without DS (n=18)	t (p)
FMS1 (score)	2.00 (0.943)	2.61 (0.608)	2.091 (0.460)
FMS2 (score)	1.30 (0.483)	2.67 (0.485)	7.154 (<0.001)
FMS3 (score)	1.10 (0.568)	2.83 (0.383)	9.643 (<0.001)
FMS4 (score)	1.50 (0.527)	2.50 (0.514)	4.886 (<0.001)
FMS5 (score)	2.80 (0.422)	3.00 (<0.001)	2.044 (0.510)
FMS6 (score)	1.40 (0.699)	2.33 (0.970)	2.672 (0.130)
FMS7 (score)	1.30 (0.483)	1.94 (0.236)	4.775 (<0.001)
FMS-total (score)	11.40 (2.503)	17.89 (1.605)	8.382 (<0.001)

Values are presented as mean (SD).

FMS: functional movement screen, DS: Down syndrome. The scores are representative of individual scores in the following components of FMS-FMS1: deep squat, FMS2: hurdle step, FMS3: inline lunge, FMS4: shoulder mobility, FMS5: active straight leg raise, FMS6: trunk stability push-up, FMS7: quadruped rotary stability.

with DS demonstrated lower ankle stability in comparison to adults without DS. Based on the significant differences ($p < 0.05$) showed in the FMS tests, we were able to confirm that adults with DS demonstrated lower ankle stability and balance in comparison to adults without DS.

The adults with DS who showed poor results on the MMT also showed a tendency to fall the moment the test began. In this study, the inline lunge included in the FMS was conducted to observe the overall balance and muscular strength of the ankle. As a result, although the adults with DS did not fall, most of them failed to complete and gave up in the middle of the process. ROM was normal in adults with DS; therefore, their lack of muscular strength made it impossible for them to maintain their dynamic balance. This result are related to previous studies using ankle strengthening exercises as an intervention to improve dynamic balance. Balance and strength improvements are very important for adults with DS, since they can produce greater stability while performing activities of daily living or work related tasks and thus, decreasing the occurrence of accidents or falls resulting in a lower incidence of injuries [26]. Accordingly, to enhance the dynamic stability of adults with DS; at ankle level, it is necessary to improve their ankle stability through strengthening exercises of their ankle plantar and dorsal flexors.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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