The Effect of Resistance and Balance Training on Postural Control and Physical Fitness in Adults with Down Syndrome

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INTRODUCTION

As individuals age, physical function plays a vital role in health and independence [1]. Low physical function was associated with musculoskeletal health conditions, such as loss of muscle mass and an increased risk of falls [2]. Although, the aging population with Down syndrome (DS) is increasing as a result of improved healthcare services provided in the community in the past seven decades [3,4], the ageing population in this group is at an increased risk of deconditioning and morbidity induced by DS [5]. The presence of an additional third chromosome 21 or trisomy 21 caused by a chromosomal disorder due to an error in cell division, as is characteristic of DS, results in precocious ageing within this group [6].

Moreover, numerous studies have reported that individuals with DS are inherently prone to joint laxity, muscle hypotonia, low levels of muscle strength, and deficits of the cerebellum [6,7]. Muscle hypotonia is suggested to be directly related to impaired postural control and gait alterations [8,9]. Motor disability is most common in individuals with DS and it includes longer motion and reaction times, stability and postural deficits [10,11]. These limitations in physical function lead to neuromuscular disorders, such as hallux valgus, hammer toe deformities, plantar fasciitis, and flat feet, which impair ambulation and cause further dysfunction [6].

In particular, people with an intellectual disability have a rapid initial
decrease in muscle mass which is a symptom associated with premature aging, and this symptom indicates a rate of functional decline with respect to lower limb muscle strength in the early forties [12-15]. Interventions that prevent low physical function are the most important to maintain activities of daily living (ADL), prevent the need for care dependency and increased healthcare costs [16-18]. Therefore, adequate exercise training, which is considered appropriate for muscular disorders, is needed to maintain and enhance physical function in older individuals with DS.

In general, resistance exercises are known to be more effective in increasing muscle mass than aerobic exercises [19], however, most studies have reported the effects of aerobic exercise [20,21] and combined exercise [22,23]. Carmeli et al. [24] reported that low muscle mass and strength have a role to play in the early onset of functional deterioration in older individuals with intellectual disability. However, only a few studies [25,26] have examined the effects of resistance training in individuals with DS, especially in adults or the elderly with DS.

Additional study on maintaining the physical ability and managing health of in adults or the elderly with DS are needed. Moreover, DS has a short life span and deteriorated with age, therefore In particular, there are few studies on individuals with DS residing in nursing homes that require a lot of care.

Therefore, we examined the effect of resistance and balance training exercises that were considered appropriate for muscular disorders, in the prevention of muscular disease. Their effectiveness in enhancing muscular strength for postural control and preventing falls in individuals with DS was also evaluated.

**METHODS**

1. **Subjects**

The subjects in this study consisted of 20 people (female, n = 5; male, n = 15) with intellectual disabilities aged between 30 to 50 years old in 1 city (mean age: 44.55 ± 7.25 years). All the participants were residents of a nursing home in 1 city and informed about the experiment. The only subjects selected were those with intellectual disabilities due to DS. These participants did not exercise regularly within 6 mos. Additional inclusion criteria include: 1) Functional ability sufficient to understand conversation, exercise guidance, and direction, 2) Reside in a supported living condition have a caregiver. Participants with intellectual disabilities, such as those caused by encephalitis, meningitis, disorders due to metabolic disorders, vitamin deficiency, and tumors were excluded from the study. All the participants were independent ambulators. The participants provided informed consent to participate in the study and this study was approved by the Ethical Committee of the Dongguk University institutional review board community (DUIRB-201708-01).

2. **Physical examination**

Anthropometric measurements were performed by trained and certified observers. Height, body weight, and body fat percent were recorded (INBODY 270, InBody, Korea). Body mass index (BMI) was calculated using the ratio of weight (kg)/height (m^2). Waist circumference was determined at the level of the natural waist between the ribs and the iliac crest at the end of a normal expiration.

3. **Physical fitness**

After a brief warm-up, participants from the experimental (EX) and control groups (CON) were measured for their physical fitness. The following measurements were included:

1) **Sit-to-stand test**

This tests muscle endurance and is a measure of the time taken to complete a full stand from a seated position. During the test, subjects were required to fold their arms across their chest in order to use as much of their lower muscle strength as possible. The reliability of this test for adults with intellectual disabilities was reported to be 0.72 [27].

2) **Grip strength**

To measure muscle strength. Subjects were required to stand with their legs at shoulder width apart and lower their arms to the side. The grip was adjusted to match the second bar of your finger. The participants were then instructed to hold the dynamometer with one hand and grip it as hard as they could. The right and left sides were examined twice and the best values were recorded. The reliability of this test for adults with mental disabilities was reported to be 0.94 [27].

3) **Incremental shuttle walking test (ISWT) for 10 m**

It is a test in which a participant walks a distance of 10 m with the inspector at a speed of 0.50 m/s. Every minute, the inspector increases the speed by 0.17 m/s according to the inspection method. The time is estimated by recording the distance walked at a given speed, allowing the participant to maintain their speed [28].
4) The 5 m walking test
This is an estimate of the force of movement and a combination of strength and dynamic balance. This test measures the time taken to walk a 5 m straight distance on a flat ground with the usual gait, paying attention not to run. The reliability of the test for the mentally disabled was reported to be 0.96.

4. Static postural control examination
This method measures the ability to control a standing posture. The subject stands on the balance force platform (Zebris PDM-system, Zebris Medical GmbH, Germany) for 1 minute with their feet shoulder width apart. They were asked to maintain their standing position with open eyes focusing on a 6 m black circle 1.5 m away in their vision line [29]. The degree of sway in millimeters while standing and the difference between the weight load on the left and right were measured.

5. Exercise program
The exercise program was managed and assisted by a team of five exercise specialists. Three special sports specialists and two exercise specialists instructed the strength and balance exercise program. In the morning and afternoon, 10 DS patients participated in the exercise program. Each class consisted of five people and there were four exercise program classes, from 09:00 am to 10:00 am, 10:30 am to 11:30 am, 14:00 to 15:00 pm, and 15:30 to 16:30 pm. Every session was composed of 60 minutes including a 10-minute warm-up, followed by 40 minutes of resistance training, and a 10-minute cool-down. All movements were repeated 15 times during a given time and three sets were performed. Exercise intensity was used as rating of perceived exertion (RPE) and was set at moderated intensity (12-13 level). This was done 3 times per week for 8 weeks. In order to improve abnormal postural stability and walking patterns in patients with DS, exercises that can improve the deformation of hip and knee joint were required. Since resistance and stretching exercises have been suggested for improving postural stability and walking ability, the exercise program in this study consisted of exercises that are known to strengthen the muscles around the hip joint and ankle joint, and it included stretching for the lower back muscles. In particular, a muscle strengthening program of the gluteus maximus, gluteus medius, quadriceps femoris, adductor magnus, tibialis posterior, ankle flexor and extensor muscle, and a stretching program of the iliopsoas and biceps femoris were the focus areas in this study. Additionally, it is important to note that careful attention should be given to stretching the muscles of a patient with DS, because they are inherently loose in the joints and ligaments. Therefore, the stretching program consisted of dynamic movements because light dynamic stretching is preferred over static stretching to prevent injury during exercise [30]. Taking these factors into consideration, the exercise program used in this study is shown in Table 1.

6. Statistical analysis
Results were expressed as mean ± standard deviation using the SPSS/PC statistic program (version 20.0 for windows; SPSS, Inc., Chicago, IL, USA). Independent t-test was used to determine the significant differences of comparisons between the groups at baseline. The changes in body composition, postural control, and physical fitness pre and post the resistance and balance exercise program were assessed by Two-way repeated analysis of variance. Differences were considered statistically significant if α = .05.

RESULTS
After the 8-week resistance and balance training program, the changes in body composition are shown in Table 2. Body weight (p < .05), BMI (p < .05), body fat percent (p < .05) and waist circumference (p < .001) showed the effect of interaction between time and group except fat-free mass.

The changes in center of pressure (COP) and standing foot pressure difference after 8 weeks of the resistance and balance training program are shown in Table 3. COP showed a significant difference after the exercise training program (p < .01) and the effect of interaction between time and group (p < .001). Weight load difference showed a significant difference after the training program (p < .05), between groups (p < .01), and the effect of interaction between time and group (p < .05).

The changes in fitness factors after 8 weeks of the strength and balance program are shown in Table 4. The number of sit-to-stand repetitions showed a significant difference after the exercise program (p < .05), and the number of repetitions in both groups increased significantly. The 10 m shuttle time also showed a significant difference after the exercise program (p < .01), and the EX group showed a significantly improved 10 m shuttle time.
The combined 8-week exercise program for individuals with Down syndrome

Table 1. The combined 8-week exercise program for individuals with Down syndrome

| Exercise                      | Type                                                                 | Time       |
|-------------------------------|----------------------------------------------------------------------|------------|
| Warm-up                       | To improve physical activity with music                             | 10 minutes |
|                               | - Balloon volleyball                                                |            |
|                               | - Grabbing balloon                                                  |            |
|                               | - Trampoline walking                                                |            |
|                               | - Bicycle at low intensity                                          |            |
| Resistance & Balance training | To improve upper and lower muscle strength and balance ability      | 40 minutes |
|                               | Upper muscle strength program with an elastic band                  | 15 repetitions each |
|                               | - Internal & external rotation exercise                             | 100 seconds |
|                               | - Chest press                                                       | 100 seconds |
|                               | - Standing row                                                      | 100 seconds |
|                               | - Crawling (10 m shuttle)                                           | 60 seconds |
|                               | Lower muscle strength program                                       | 15 repetitions each |
|                               | - Sit-to-stand                                                      | 40 seconds |
|                               | - Calf raises against the wall                                      | 40 seconds |
|                               | - Side lunge                                                        | 100 seconds |
|                               | - Rabbit jump (10 m) & trampoline jump (10 repetitions): 3 times    | 60 seconds |
|                               | Balance program                                                     |            |
|                               | - Walking on the heel (10 m shuttle)                                | 30 seconds |
|                               | - Kick to front & back (15 repetitions each)                        | 120 seconds |
|                               | - Bounce on a gym ball (30 times)                                   | 50 seconds |
|                               | - Touch the left and right bottom with hands while sitting on a gym ball (30 times) | 50 seconds |
|                               | All movements were performed at 3 sets.                             |            |
| Cool-down                     | Stretching in a sitting position or lying down                      | 10 minutes |
|                               | - Stretching for back, hip, and calf with a foam roller             |            |
|                               | - Stretching the back in a sitting position with legs together & open|            |
|                               | - Roly poly                                                         |            |
|                               | - Passive stretch of the lower back & hip joint                     |            |

Table 2. Changes in body composition after the resistance and balance training program

| Variables     | Group | Pre      | Post     | F     | Sig. |
|---------------|-------|----------|----------|-------|------|
| Weight (kg)   | EX    | 64.52 ± 12.81 | 62.88 ± 12.47 | T    | 2.743 | .120 |
|               | CON   | 69.90 ± 7.70  | 70.32 ± 8.41  | G    | 1.31  | .263 |
|               |       |            |            | T*G  | 8.033 | .013*|
| BMI (kg/m²)   | EX    | 25.18 ± 5.51  | 24.54 ± 5.53  | T    | 3.612 | .078 |
|               | CON   | 26.48 ± 2.65  | 26.62 ± 2.71  | G    | .552  | .470 |
|               |       |            |            | T*G  | 8.966 | .010*|
| FFM (kg)      | EX    | 25.88 ± 4.48  | 26.63 ± 4.99  | T    | .438  | .518 |
|               | CON   | 25.14 ± 4.85  | 24.80 ± 4.61  | G    | .313  | .584 |
|               |       |            |            | T*G  | 3.192 | .094 |
| % FAT (%)     | EX    | 31.08 ± 5.75  | 28.43 ± 6.74  | T    | 1.924 | .186 |
|               | CON   | 29.61 ± 7.17  | 30.19 ± 6.75  | G    | .002  | .963 |
|               |       |            |            | T*G  | 4.667 | .047*|
| Waist (cm)    | EX    | 87.0 ± 11.27  | 84.15 ± 10.52 | T    | 2.401 | .142 |
|               | CON   | 92.0 ± 6.50   | 93.0 ± 7.63   | G    | 2.193 | .159 |
|               |       |            |            | T*G  | 10.401| .006**|

T, time; G, group; T*G, the interaction between time and group; EX, exercise group; CON, control group; BMI: body mass index; FFM, fat-free mass; %FAT: body fat percent.

DISCUSSION

The exercises used in this study consisted of strength and balance training to improve musculoskeletal problems for upper and lower extremity strength and postural balance in patients with DS. After 8 weeks of strength and balance training in this study, body composition, bal-
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ance ability, and physical fitness factors such as sit-to-stand repetitions and ISWT walking time improved significantly.

Long-term exercise has been reported to reduce body fat and increase muscle mass in a study of people with intellectual disabilities [20]. However, in a study where aerobic and resistance exercises were performed separately by patients with DS, aerobic exercises decreased body weight and body fat percent [20,21], however, resistance exercises have shown inconsistent results [23,31]. In this study, resistance and balance exercises for 8 weeks significantly decreased body weight, BMI, and body fat percentage. Moreover, fat free mass increased in the EX group, but this result was insignificant. Insignificant changes in fat free mass were probably due to a relatively short period of the exercise intervention (8 weeks), and it is plausible that a longer period of intervention might result in a greater improvement in fat free mass.

The result of the changes in body composition after a relatively short-term resistance training program was significant. An increase in BMI is related to an increase in functional impairment [32], which may induce an impaired balance and increase the risk of falling thereby causing postural stress and perturbation [33,34], even in individuals aged under 40 years [35,36]. However, weight reduction has a favorable impact on postural instability [36]. Participants with DS in this study showed a higher BMI and body fat percent before the exercise program. Therefore, when considered together, a high body weight and the physical characteristics of DS, can impact postural balance negatively.

Furthermore, DS was reported to reduce an individual’s capacity to maintain postural stability, because postural stability requires the simultaneous combination of motion and stability of the ankle and hip [37]. It has been reported that a decrease in muscle hypotonia induces muscle weakness, more flexibility in the joint than necessary, and low balance ability in patients with DS. In this study, patients with DS showed a higher frequency of postural sway and a greater difference between weight load on the left and right in the standing position before the exercise program. However, the EX group had reduced postural sway and a lower difference between weight load on the left and right in the standing position after the 8-week exercise program. A previous study recommended that strengthening the ankle flexors and extensors and balance training to improve medial-lateral control using hip strategies should be considered in rehabilitation programs [38]. As our training program in this study focused on the ankle and hip joint muscle group, this program could have a favorable impact on postural balance as well as body

Table 3. Changes in COP and standing foot pressure after the strength and balance training program

| Variables             | Group | Pre          | Post          | F   | Sig. |
|-----------------------|-------|--------------|---------------|-----|------|
| COP (mm)              | EX    | 1,495.08 ± 910.09 | 145.71 ± 58.81 | T   | 25.039 | .000 |
|                       | CON   | 1,466.17 ± 1,096.89 | 1,418.37 ± 931.08 | G   | 1.798  | .200 |
|                       |       |              |               | T*G | 11.931 | .004 |
| Weight load (kPa)     | EX    | 31.96 ± 18.34 | 13.94 ± 4.76  | T   | 8.295  | .011 |
|                       | CON   | 47.13 ± 18.76 | 45.58 ± 17.09 | G   | 11.239 | .004 |
|                       |       |              |               | T*G | 5.868  | .029 |

EX, exercise group; CON, control group; COP, center of pressure.

Table 4. Changes in physical fitness after 8 weeks of the strength and balance training program

| Variables             | Group | Pre          | Post          | F   | Sig. |
|-----------------------|-------|--------------|---------------|-----|------|
| Sit-to-Stand (number) | EX    | 9.55 ± 4.29  | 13.36 ± 3.88  | T   | 6.599 | .021 |
|                       | CON   | 10.71 ± 3.25 | 11.43 ± 2.50  | G   | .061  | .808 |
|                       |       |              |               | T*G | 3.095  | .098 |
| Muscle Strength (kg)  | EX    | 14.58 ± 7.73 | 16.84 ± 6.55  | T   | 1.367 | .258 |
|                       | CON   | 16.82 ± 7.61 | 16.42 ± 7.31  | G   | .076  | .785 |
|                       |       |              |               | T*G | 2.793  | .113 |
| ISWT (sec)            | EX    | 125.09 ± 33.49 | 195.86 ± 95.18 | T   | 10.399 | .005 |
|                       | CON   | 107.43 ± 36.85 | 151.09 ± 34.44 | G   | .592  | .453 |
|                       |       |              |               | T*G | 3.095  | .098 |
| 5 m walking (sec)     | EX    | 5.36 ± 1.40  | 5.02 ± 1.06   | T   | 0.452 | .511 |
|                       | CON   | 5.82 ± .70   | 5.68 ± 1.82   | G   | 1.175 | .294 |
|                       |       |              |               | T*G | .074   | .789 |

EX, exercise group; CON, control group; ISWT, 10 m incremental shuttle walking test.
weight reduction.

In this study, the number of sit-to-stand repetitions and the 10 m shuttle time increased after 8 weeks. Skeletal deformation of the foot in DS causes extensive fatigue in the calf and foot after repeated walking and weakening of the tibialis posterior, which assists the longitudinal arch [39]. Passive and active massage or stretching and tibialis posterior strengthening exercises are required to improve calf muscle and plantar fatigue. Additional exercises were recommended as balance exercises that were closely related to one’s ability to walk, for example, standing up against the wall with raised toes, standing in place with the heels up, and walking on the heel [37]. Our training focused and consisted of a program based on these strategies, therefore, the participants with DS in the EX group in this study showed an improvement in lower muscle endurance and the 10 m shuttle duration.

Previous studies of resistance training alone reported significantly improved maximal muscle strength after upper and lower muscle exercises 3 times per week [25,40], however, resistance training alone was shown to have limited improvements in maximal muscle strength after upper and lower muscle exercises twice per week [26]. However, it has been reported that muscle strength improved after aerobic exercises that targeted a large muscle group of the body were performed twice a week, and previous studies suggested that combined exercises were more effective than resistance exercises alone. In other words, combined exercises showed improvement in cardiopulmonary function as well as muscle strength and these results suggest that combined exercises are more efficient than aerobic or strength exercises alone.

However, inherit musculoskeletal dysfunction in DS causes secondary muscle loss and body deformation, resulting in various musculoskeletal disorders and joint instability [6]. Therefore, we suggested that strength training to improve these musculoskeletal problems should be performed at the beginning of an exercise class and then proceed to combined exercises. This strategy is expected to be more effective in preventing injury, fatigue, and falls that can occur during exercise and to improve the health in individuals with DS.

As a result of this study, it was found that balance, muscular endurance, and walking capacity were increased after 8 weeks. Our training program in this study focused on the ankle and hip joint muscle group, this program could have a favorable impact on postural balance as well as body weight reduction. Our training also focused and consisted of a program based on related to one’s ability to walk balance. Therefore, training program of this study that increase muscle strength related to balance was effective in improving muscular strength for postural control and preventing falls in individuals with DS.

CONCLUSION

This study was conducted on individuals with DS living in the same area, the diet and lifestyle habits had the similar patterns, because participants were residents in nursing home. Therefore, exogenous variable that may affect the the effect of exercise were minimized. However, as a limitation of our study, the number of subjects were only 20, and the study period was only 8 weeks. Further study are needed to expand to larger study population and apply a longer period of exercise duration.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

AUTHOR CONTRIBUTIONS

Conceptualization: YA Shin; Data curation: JS Lee; Formal analysis: HB Jeong; Funding acquisition: SM Hong; Methodology: YA Shin; Project administration: SM Hong; Visualization: JS Lee; Writing-original draft: YA Shin; Writing-review & editing: SM Hong.

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