SINTA 2 (Decree No: 177/E/KPT/2024) Available online at https://e-journal.unair.ac.id/SPMRJ

Original Article

The impact of periodized sit-to-stand exercises on enhancing gross motor skills and balance in children with Down Syndrome

Marietta Shanti Prananta[1], Dian Marta Sari[1], Ika Ayu Paramita[1], Nurvita Trianasari[2], Laurentia Cindy Gani Wijaya[3], Patricia Helena Christiani Santoso[4]

[1]*Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia*
[2]*Economics and Business School, Telkom University, Bandung, Indonesia*
[3]*General Practitioner, Siloam Hospitals Kebon Jeruk, Jakarta, Indonesia*
[4]*General Practitioner, Regional Public Hospital Cikalongwetan, Bandung, Indonesia*

Correspondent
Dian Marta Sari, Department of Physical Medicine and Rehabilitation, Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia
E-mail: dian.marta@unpad.ac.id

Article info:

Received: December 4, 2024

Received in revised: June 2, 2025

Accepted: July 15, 2025

Published: August 25, 2025

Cite this as: Prananta, M. S., et. al. The Impact of Periodized Sit-to-Stand Exercises on Enhancing Gross Motor Skills and Balance in Children with Down Syndrome. SPMRJ Vol. 7 No. 2. 164-181. https://e-journal.unair.ac.id/SPMRJ/article/view/66296

ABSTRACT

Background: Down Syndrome (DS) is a congenital chromosomal disorder that leads to various impairments including delayed motor development, hypotonia, ligamentous laxity, and poor balance. Strengthening exercises are considered beneficial in improving motor and balance functions in these children. This study aimed to evaluate the effects of a periodized sit-to-stand exercise program on the gross motor and balance abilities of children with DS.

Materials and Methods: Sixteen children aged 7–12 years from the Perhimpunan Orang Tua Anak dengan Down Syndrome (POTADS) in Bandung participated in a quasi-experimental study using a pretest-posttest group design. The intervention consisted of sit-to-stand strengthening exercises performed three times weekly for seven weeks at home. The training load was set at 30% of the one-repetition maximum (1RM) in the first week and progressively increased to 40%, 50%, and 60% in the subsequent weeks, followed by recalculated 1RM and increased loads of 50%, 60%, and 70% during weeks five–seven. Assessments were conducted using Gross Motor Function Measure (GMFM) dimensions D and E and the Pediatric Balance Scale (PBS).

Results: The study showed significant improvements in GMFM dimension D (standing; mean increase: 5.31 ± 2.97, P=0.0001), GMFM

DOI: 10.20473/spmrj.v7i2.57895

dimension E (walking, running, jumping; mean increase: 16.32 ± 6.73, P=0.0001), and PBS (balance; mean increase: 9.37 ± 3.66, P=0.0001).
Conclusion: Periodized sit-to-stand strengthening exercises significantly improved gross motor skills and balance in children with DS.

Keywords: *Balance, Down Syndrome, Health and Well-being, Motor skill, Periodization, Strengthening exercise*

INTRODUCTION

Down Syndrome (DS), also known as trisomy 21, is a genetic disorder caused by an extra copy of the chromosome 21. Data from the World Health Organization (WHO) shows that around 3,000 to 5,000 children are born with DS each year and there are currently an estimated 8 million individuals with DS worldwide.[1,2]

The addition of chromosome 21 causes changes in the brain structure. Differences in brain structure will cause impaired motor development and musculoskeletal system disorders that affect daily activities because balance is controlled from the central nervous system and requires muscle strength to fight gravity and other external loads.[3] Disorders that often occur in DS are hypotonus, ligament laxity, decreased muscle strength where the largest joint laxity is the hip and ankle joints.[4]

Children with DS have a 50% lower muscle strength than children without DS.[5] Cioni et al. reported that children with DS have weakness in the pelvic abductor and knee extensor muscles.

Weakness of lower limb muscles and joint laxity results in disruption of balance because they cannot maintain body position both statically and dynamically and can increase the risk of falls in children with DS.[5,6] In children with DS, both gross and fine motor development patterns will be achieved at a slower pace than normal children.[1]

Gross motor development is generally evaluated using the Gross Motor Function Measure-88 (GMFM-88), a scale for quantitative evaluation without regard to the quality of motor performance that can be used in children from birth to 16 years of age. This study used GMFM dimensions D and E because they represent children's motor abilities in performing daily and school activities. The components of the GMFM D dimension are standing while the E dimension consists of walking, running and jumping. As for measuring balance in children, the Pediatric Balance Scale (PBS) is used.[3]

To improve muscle strength and balance, exercise intervention is necessary, which is an activity that is easy to perform and mechanically a functional activity that children perform during their daily routine. Sit-to-stand exercise with weights in children with cerebral palsy is proven to improve lower limb muscle strength and balance as shown in increased walking speed, decreased energy expenditure and increased knee extensor strength.[7-9]

Exercise interventions have been widely used to enhance muscle strength and balance in several populations. Among these, sit-to-stand exercises are particularly beneficial because they are functional movements routinely performed in daily activities. Sit-to-stand exercises constitute isotonic strengthening exercises designed to enhance muscle strength through muscular hypertrophy, increased neural activity, and improved motor unit recruitment.[10-12] Furthermore, these exercises stimulate proprioceptive feedback in the neck, trunk, and lower extremities, which is crucial for enhancing balance and postural control.[8]

Sit-to-stand exercise interventions have never been implemented for children with DS. Sit-to-stand exercise interventions involving weight are required to improve muscle strength and balance. Periodized exercise programs, characterized by structured variations in training intensity and volume, are particularly suitable for children with DS because of their musculoskeletal vulnerabilities such as hypotonia and joint laxity, which increase the risk of injury with high-intensity or repetitive exercises.[4] Periodization allows for gradual load progression, alternating between unloading and overloading phases, to optimize muscle adaptation while minimizing strain on joints and connective tissues. We hypothesized that a structured periodized sit-to-stand exercise program would significantly improve gross motor skills and balance in children with DS. Therefore, this study aimed to determine the effects of periodized sit-to-stand exercise on gross motor skills and balance in children with DS.

MATERIAL AND METHODS

This study used a quasi-experimental design method with a pre-test–post-test group design approach. The pretest-posttest group design was conducted by assessing before and after treatment in one group, namely, a sit-to-stand exercise program conducted at home between June and September 2022.

Consecutive sampling was used in this study. The sample size was determined using a priori sample size calculation based on a 95% confidence level ($Z\alpha = 1.64$) and 95% power ($Z\beta = 1.64$), following the Deming rule. The calculation yielded a minimum sample of 16 participants, which was used for this study.[13] The research stages are illustrated in Figure 1.

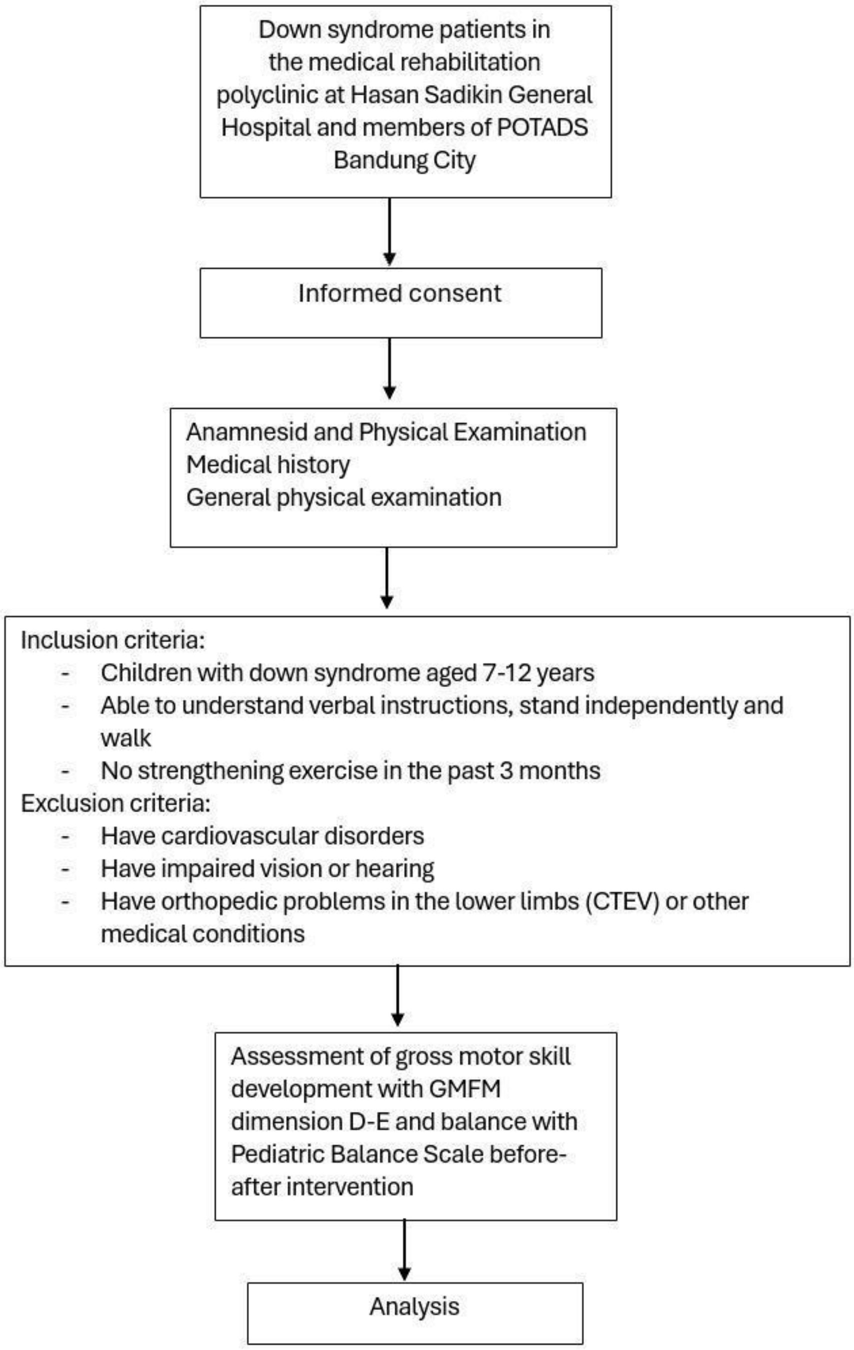

Figure 1. The research stages

The special exclusion criterion (drop out) was whether the research subject did not perform the exercise three times in a row or did not perform the exercise more than five times.

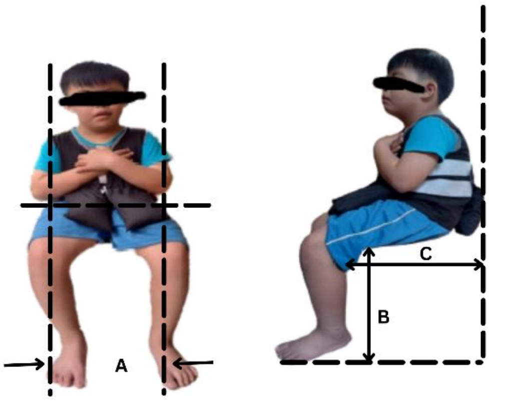

Figure 2. Chair Measurement. A = Seat width: 1 inch wider than the broadest part of the hip. B = Seat height: from the bottom of heel to the popliteal region. C = Seat depth: from the popliteal region to the back of the hip.

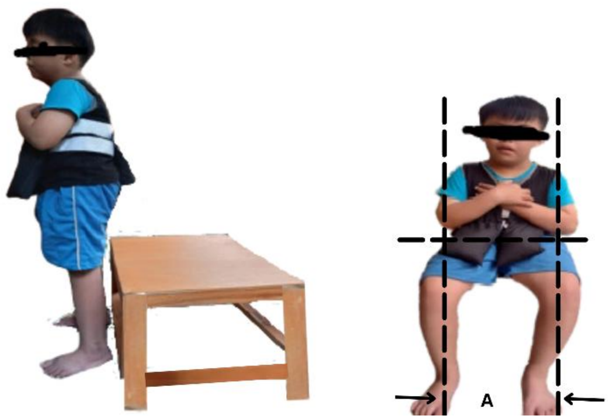

Figure 3. The child was seated on a chair, which was measured accordingly

The intervention was performed as follows:

1) The subject performed a maximal load test (1 RM) on the sit-stand test, which is the maximum load that the research subject is able to perform when standing from a sitting position for one time without falling, beginning with a warm-up of muscle stretching for 5 min before training. The height of the chair was adjusted to the research subject in the initial position when sitting at hip flexion 90°, knee flexion 105°, and ankle dorsiflexion 15°; the legs were

parallel, the torso was upright, and the hands were on the waist or crossed on the chest (Figure 2 and 3). [9,12]

2) Test 1 RM was performed if the subject was familiar with exercise movements. The subject started the exercise by performing the sit-to-stand movement correctly, namely sitting for 2-3 seconds and standing for 2-3 seconds. Subsequently, the subject performed the 1 RM test. The load was calculated from 30% of body weight, and with a trial-error system, the load was increased or decreased by 0.5-1 kg according to the child's. The subjects rested for 2 minutes between the tests. The weights are put into a bag and then attached to the jacket and placed evenly on the subject's body parts.[14]

3) The subjects performed home-based exercise interventions.

4) The subjects were given a sit-to-stand exercise program of three sets, three times per week, for seven weeks. The exercises were interspersed with 2 minutes rest between sets. Sit-to-stand strengthening exercises with weights are carried out for approximately 20-30 minutes per session, starting with a warm-up and ending with a cool-down for 5-10 minutes in the form of stretching the thigh joint adductor muscles, plantar flexor ankle, hamstring, and lumbar extensor.[9,14]

5) In the first week, the subjects performed sit-to-stand exercises without weight (body weight) for three sets of 10 repetitions, introducing the exercises and training to perform the exercises correctly to the caregiver and research subjects. In the second week, the subjects began to perform sitting-standing strengthening exercises with a jacket load (40% of 1RM) for three sets, interspersed with 2 min of rest with 10 repetitions. The load on the research subjects was increased to 50% of 1RM in the third week and 60% of 1RM in the fourth week. [9,14]

6) The researcher re-measured the maximum load of the 1 RM sit-to-stand test at the end of the fourth week. The load was re-measured in the fifth, sixth, and seventh weeks at 50%, 60%, and 70% of 1 RM attached to the table; therefore, for seven weeks, there was an unloading phase and an overloading phase. The researcher was assisted by a standardized doctor to monitor the implementation of sit-to-stand

strengthening exercises with weights by the caregiver through videocalls or exercise diaries filled in by the subject and visited the research subject's home once a week.[9,14]

7) Data were excluded if the subject lost balance, stood in an uneven posture, could not stand steadily for 2 s, or moved the trunk excessively and abruptly when trying to sit or stand.

The subjects were evaluated using the GMFM dimensions D-E and PBS before and after receiving the intervention as follows.

Table 1. Prescription for Sit-to-Stand Strengthening Exercises with a 12-Week Load[9,14]

Week	Objective	Set	Repetition	Load	Rest
1	Introducing the type of exercise and training to perform it correctly (caregiver and research subjects)	**1**	**10**	**Body weight**	**2 minutes**
		2	**10**		
		3	**10**		
2	Increasing exercise intensity	**1**	**10**	**40% of 1 RM**	**2 minutes**
		2	**10**		
		3	**10**		
3	Increasing exercise intensity	**1**	**10**	**50% of 1 RM**	**2 minutes**
		2	**10**		
		3	**10**		
4	Increasing exercise intensity	**1**	**10**	**60% of 1 RM**	**2 minutes**
		2	**10**		
		3	**10**		
	Conducting 1 RM Test				
5	Increasing exercise intensity	**1**	**10**	**50% of the new 1 RM**	**2 minutes**
		2	**10**		
		3	**10**		
6	Increasing exercise intensity	**1**	**10**	**60% of the new 1 RM**	**2 minutes**
		2	**10**		
	Conducting 1 RM Test	**3**	**10**		
7	Increasing exercise intensity	**1**	**10**	**70% of the new 1 RM**	**2 minutes**
		2	**10**		
		3	**10**		

Data Analysis Technique

The collected data were processed and analyzed descriptively and analytically. Statistical testing began with a normality test using the Shapiro-Wilk test (n<50), followed by significance testing to compare the pre-post characteristics of the research groups (using the paired t-test if the data were normally distributed and the Wilcoxon test if data were not normally distributed).

Categorical data were analyzed using the McNemar's test. The data obtained is recorded in a special form and processed using SPSS version 25.0.[12]

RESULTS

Characteristics of Research Subjects

The research subjects were children with DS who were part of the Perhimpunan Orang Tua Anak Down Syndrome (POTADS) community in Bandung City, as well as students from special schools and inclusive schools in and around Bandung who met the research criteria and completed a 7-week therapy program (with a training frequency of three times per week). The total number of subjects who completed the sit-to-stand exercise program was 16. There were no missed sessions due to pain or injury resulting from the exercise program.

The characteristics of the research subjects based on sex, age, weight, and height are shown in Table 2.

Table 2. Characteristics of Research Subjects

Variable	**N=16**
Age Mean±Std	9.21±1.884
Median	8.71
Range (min-max)	7.00-12.83
Sex Male	9(56.3%)
Female	7(43.8%)
Weight (kg) Mean±Std	24.78±6.607
Median	24.50
Range (min-max)	15.00-36.80
Height (cm) Mean±Std	121.75±14.154
Median	123.00
Range (min-max)	100.00-146.00
BMI (Kg/m2) Mean±Std	16.74±3.851
Median	16.45
Range (min-max)	11.80-26.40

BMI: Body mass index.

Table 3. Changes in GMFM-D, GMFM-E, PBS, and load Before and After Exercise

Variable	Before Exercise	After Exercise	P-value
	N=16	**N=16**	
GMFM-D Mean±Std	30.88±5.136	36.19±2.167	0.0001** [a]
Median	30.50	36.00	
Range (min-max)	21.00-39.00	33.00-39.00	
GMFM-E Mean±Std	47.56±9.899	63.88±7.164	0.0001** [b]
Median	50.50	65.50	
Range(min-max)	33.00-65.00	41.00-72.00	
PBS Mean±Std	44.38±5.353	53.75±2.408	0.0001** [b]
Median	45.50	55.00	
Range (min-max)	34.00-54.00	48.00-56.00	
Load Mean±Std	7.84±2.103	10.44±2.798	0.0001** [a]
Median	8.00	11.00	
Range (min-max)	4.50-11.00	6.00-15.00	

Note: [a] test using paired t-tests; [b] test using the Wilcoxon test. The significance level was based on a P-value of < 0.05. GMFM: Gross Motor Function Measure; PBS: Pediatric Balance Scale.

Statistical analysis of the research group showed significant results (P-value < 0.05), indicating a significant difference in GMFM-D, GMFM-E, PBS, and load variables before and after the 7-week periodized sit-to-stand strengthening exercise program.

The results demonstrated significant improvements across various functional domains including standing, walking, running, jumping, and balance. These findings suggest that the intervention effectively enhanced participants' gross motor function and balance capabilities.

DISCUSSION

In this study, periodized sit-to-stand strengthening exercises significantly improved gross motor skills and balance in children with DS, as evidenced by increases in Gross Motor Function Measure (GMFM) dimensions D and E, and the Pediatric Balance Scale. These findings align with previous research demonstrating the efficacy of resistance training in enhancing motor function and balance in children with DS and other neurodevelopmental conditions, such as cerebral palsy.[9,12,14,23]

Characteristics of Research Subjects

In this study, participants were selected based on the need for high physical activity, as this age group corresponds to school age, when children are active at home, school, and in the community. Gupta et al. also stated that children with DS aged 5 to 17 years have functional and skill impairments, as indicated by low Weefim scores.[15]

Children with DS are at higher risk of developing obesity. According to Artioli, the physiological factors causing obesity in children with DS include hypothyroidism, reduced resting metabolic rate, increased leptin levels, masticatory dysfunction, and low lean body mass.[16] Low lean body mass is associated with muscle weakness, reduced functional capacity, and lower maximum oxygen consumption. [16]

Obesity affects motor skills and balance and hinders children's physical activity. The results of this study show that weight, height and Body Mass Index (BMI) are within normal limits.[17] BMI influences motor skills and balance. Samire Beqaj et al. also stated that there is a relationship between BMI and motor skills as well as physical fitness, it shows that the higher the BMI, the lower the motor performance in preschool-aged children.[18] Children with obesity have lower agility and take longer to change positions. During the sit-to-stand exercise, the trunk moves backward during the preparation phase to generate sufficient body angular momentum during the transition phase and maintains an upright trunk at the end of the phase.[19] Increased BMI impacts postural instability, which can lead to balance disturbances and increase the risk of falls.[20]

Changes in GMFM Dimensions D and E Before and After Exercise

Motor skills refer to the coordination between muscles, bones, and nerves. Movements involving the use of large muscles, such as crawling, standing, climbing stairs, walking, and running, are considered gross motor skills.[20] The standing position is achieved after postural alignment between the head, body, and hips occurs. The standing ability of children with DS is challenging, because it involves both body extension and flexion. Children with DS typically have the ability to walk at an age older than three years.[3] The delay in motor skills in children with DS is due to joint laxity and hypotonia. Down Syndrome also presents with motor skill difficulties, marked by limitations in motor planning and motor control. These motor impairments can lead to delays in motor skill development and disrupt balance.[20,21]

Extensive research has been conducted on strengthening exercise. Closed kinetic chain exercises are effective for improving intermuscular coordination and strength. Strengthening exercises for children must be carefully considered because of musculoskeletal abnormalities. Therefore, exercises should be provided with correct movement instructions, clear verbal guidance, and tailored to specific needs to enhance motor skills and dynamic-static balance.[22]

Sit-to-stand exercises are a form of isotonic strengthening exercise. Isotonic exercises can be performed using internal resistance, such as body weight, or external resistance, such as barbells or weighted vests. Strength training aims to induce skeletal muscle adaptation through overload, leading to muscle hypertrophy and increased muscle strength, as well as neural system adaptation, to enhance motor unit recruitment.[22] Sit-to-stand exercises with added weight increase muscle strength by enhancing neural activity within muscles, resulting in hypertrophy and functional adaptation.[12]

Sit-to-stand strengthening exercises in this study use periodization because children with have hypotonia and joint laxity; therefore, high loads can increase the risk of musculoskeletal injury.[3,4] In this study, bags of weights were placed in the jacket at the chest level, and then the load was divided evenly on the front of the body and back.[12,23] Researchers chose to use weight jackets because the research subjects were children with who had joint laxity so that the load was not placed on the lower limbs.[4]

Load measurements were made on the research subjects 1RM before and during training at week five. The results showed an increase in the subjects' ability to carry weight. In this study, the upper and lower limbs moved against the resistance provided by gravity, body weight, and weight jackets. This process produces microcellular lesions, especially in the eccentric action phase, which activates defense systems, such as neutrophils, macrophages, and cytokines that produce reactive oxygen and nitrogen. These conditions are necessary for the muscle recovery and regeneration process due to the fusion of satellite cells with the main cells and the induction of protein synthesis metabolism.[24]

Sit-to-stand exercise is one of the various strengthening exercises intended not only for children with DS but also for children with other special needs, such as cerebral palsy. Research conducted by Sari et al, Liao et al, Misdalia et al, and Imran et al, conducted a study of sitting-standing exercises with weights in cerebral palsy children for 7 weeks and gave significant results in increasing lower limb muscle strength. Changes in muscle strength require a minimum training time of four weeks to increase nerve recruitment and changes in the size of larger muscle fibers.[9,12,14,23] A meta-analysis study concluded that the duration of the strengthening exercise program can be 6–21 weeks, but two-thirds of the studies conducted used a short time of 6-12 weeks.[25] This study used sit-to-stand strengthening exercises with periodization for 7 weeks. This is in accordance with the research conducted by Gupta et al., who performed strengthening exercises three times a week for six weeks with loads starting at 50% 1RM and increasing gradually to 70-80% of 1RM. Strengthening exercises performed by Gupta et al. showed an increase in muscle strength of the hip flexor, hip extensor, hip abductor, knee flexor, knee extensor, and ankle plantar flexor muscles.[15] These functional gains may improve independence in daily activities, such as navigating classrooms or engaging in recreational activities, thereby enhancing the quality of life.

Periodization is an exercise prescription method used not only for athletes, but also for populations that are prone to musculoskeletal injuries. Misdalia et al's research showed that there was a significant increase in value by providing a sit-to-stand exercise intervention with periodization where sit-to-stand exercise with weights not only improved motor skills of standing, walking, running and jumping.[14]

The concept of periodization in this study involves alternating unloading and overloading phases. The overloading phase was implemented during the sixth and seventh weeks, when the training load was progressively increased to 60% and 70% of the newly remeasured 1RM, respectively, following an unloading phase at 50% during the fifth week. During this period of re-adaptation to a higher load threshold, an increase in motor unit activation, recruitment, and firing rate is anticipated. This adaptation process is also associated with enhanced mitochondrial biogenesis and modulation of cellular signaling pathways that contribute to muscle hypertrophy.[26]

Changes in Pediatric Balance Scale (PBS) scores before and after training

Down Syndrome is characterized by abnormalities in the musculoskeletal and nervous systems.[7] Structural abnormalities in the brain are also accompanied by delays in the myelination of the central and peripheral nervous systems.[3] The ability to maintain balance in various positions depends on the complex integration of musculoskeletal and nervous systems. [7, 27]

Balance is maintained through interactions between the sensory and postural control systems. Postural control involves cognition, dynamic control, orientation to space, movement, and sensory strategies. Sensory information from the somatosensory, vestibular, and visual systems is integrated into the central nervous system to produce purposeful movements. Children with will reach postural control maturity at 13-14 years of age.[7]

Children with DS have postural dysfunction, which is associated with impaired motor coordination, impaired sensorimotor integration, and slower reaction times for compensatory postural changes.[3,28] During standing, children with DS are unable to control oscillations in both the mediolateral and anteroposterior directions. Children with DS also have difficulty adjusting the center of pressure (COP) so that when standing, they will widen the distance between the two limbs to maintain the base of support. Malak et al also explained that standing and walking are the most difficult tasks for them to achieve due to inadequate contraction of the flexor and extensor muscle groups needed to maintain balance.[3]

Exercise intervention is an effective method to improve balance and postural control.[7] Sit-to-stand strengthening exercises can not only increase lower limb muscle strength but also improve posture control because when the subject performs sit-to-stand exercise movements, it stimulates proprioception in the neck, trunk, and lower extremities.

During the sitting-standing movement process, the lower limb muscles are activated continuously to maintain body stability during changes in position, which can also improve balance.7 This is in accordance with the research of Pena et al who showed the effect of resistance training on improving posture control and balance.[7,8] This research design used an interventional study to provide results with a higher level of validity, although there are limitations to this study, such as the absence of a control group, which prevented definitively attributing improvements to the intervention alone, as natural development or external factors (e.g., concurrent physical activities) may have contributed, and no physical activity checks were carried out before, during, or after training to determine the effect of sitting-standing exercises with weights on gross motor skills and balance. Muscle weakness that occurs in children with will affect the high level of their physical activity, the more severe the weakness suffered, the more limited the physical activity that can be done.[3,29]

CONCLUSION

Periodized sit-to-stand strengthening exercises significantly improved gross motor skills, as measured by the Gross Motor Function Measure (GMFM) dimensions D (standing) and E (walking, running, jumping), and balance, as assessed using the Pediatric Balance Scale (PBS), in children with DS. This home-based intervention, conducted three times a week for seven weeks, offers a practical and accessible approach to enhance functional abilities in this population. Structured periodization, with progressive load increasing from 30% to 70% of the one-repetition maximum (1RM), likely contributed to these improvements by optimizing muscle adaptation while minimizing injury risk due to hypotonia and joint laxity. Parental supervision ensures consistent implementation, making it a feasible option for community settings. Further research should incorporate physical activity monitoring before, during, and after the intervention to isolate the effects of sit-to-stand exercises and include a control group to strengthen causal inferences. Studies with longer observation periods are recommended to evaluate the sustainability of motor and balance improvements, ultimately enhancing the quality of life of children with DS.

Abbreviations

BMI : Body Mass Index

COP : Center of Pressure

GMFM : Gross Motor Function Measure

GMFM-88 : Gross Motor Function Measure-88

PBS : Pediatric Balance Scale

POTADS : *Persatuan Orang Tua Anak* Down Syndrome

RM *:* Repetition Maximum

WHO : World Health Organization

DISCLOSURES

Acknowledgments

The authors express their gratitude to the Faculty of Medicine Universitas Padjadjaran for providing the opportunity to complete this manuscript.

Ethical Approval

The study was approved by the Ethics Committee of Hasan Sadikin Hospital. (Approval number: LB.02.02/X.6.5/227/ 2022)

Conflict of Interest

The authors declare that they have no conflicts of interest.

Funding sources

This study did not receive any specific grants from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contribution

MSP, DMS, and IAP designed the study concept and protocol and recruited participants for the study. IAP performed and interpreted the GMFM and PBS scores. MSP, DMS, and IAP wrote the manuscript for original draft preparation. NT performed the data curation and statistical analyses. LCGW and PHCS designed the study and edited the manuscript accordingly. MS, DMS, and IAP reviewed the process of writing the manuscript.

References

1. Irwanto, Wicaksono H, Ariefa A, Samosir SM. A-Z Sindrom Down. Surabaya: Airlangga University Press; 2019.

2. Nurwahidah S, Suwondo W, Sasmita IS. Prevalensi sindroma Down di wilayah Priangan pada tahun 2015. J Kedokt Gigi Univ Padjadjaran. 2017;29(3):185-95. Available from:

https://doi.org/10.24198/jkg.v29i3.15950

3. Malak R, Kostiukow A, Krawczyk-Wasielewska A, Mojs E, Samborski W. Delays in motor development in children with Down syndrome. Med Sci Monit. 2015;21:1904-10. Available from: https://doi.org/10.12659/MSM.893377

4. Foley C, Killeen OG. Musculoskeletal anomalies in children with Down syndrome: an observational study. Arch Dis Child. 2019;104(5):482-7. Available from: https://doi.org/10.1136/archdischild-2018-315751

5. Amini HA, Kalkhoran JF, Salehi M, Jazini F. Effect of backward walking training on improving postural stability in children with Down syndrome. Iran J Pediatr. 2016;26(4):e4188. Available from: https://doi.org/10.22038/ijp.2016.7103

6. Eid MA. Effect of whole-body vibration training on standing balance and muscle strength in children with Down syndrome. Am J Phys Med Rehabil. 2015;94(8):633-43. Available from: https://doi.org/10.1097/PHM.0000000000000224

7. Maïano C, Hue O, Lepage G, Morin AJS, Tracey D, Moullec G. Do exercise interventions improve balance for children and adolescents with Down syndrome? A systematic review. Phys Ther. 2019;99(5):507-18. Available from: https://doi.org/10.1093/ptj/pzz012

8. Pena GM, Pavão SL, Oliveira MFP, Godoi D, de Campos AC, Rocha NACF. Dual-task effects on postural sway during sit-to-stand movement in children with Down syndrome. J Intellect Disabil Res. 2019;63(6):576-86. Available from: https://doi.org/10.1111/jir.12599

9. Sari DM, Shanti M, Hilmanto D. Peningkatan kemampuan berjalan dan energy expenditure pada palsi serebral yang menjalani latihan penguatan dengan metode periodisasi. Maj Kedokt Bandung. 2017;49(1):48-54. Available from: https://doi.org/10.15395/mkb.v49n1.987

10. Melo GLR, Neto IVS, da Fonseca EF, Stone W, Nascimento DDC. Resistance training and Down Syndrome: A narrative review on considerations for exercise prescription and safety. Front Physiol. 2022 Sep 27;13:948439. doi: 10.3389/fphys.2022.948439.

11. Da Costa CSN, Savelsbergh G, Rocha NACF. Sit-to-stand movement in children: a review. J Mot Behav. 2010;42(2):127-34. Available from: https://doi.org/10.1080/00222891003612763

12. Liao HF, Liu YC, Liu WY, Lin YT. Effectiveness of Loaded Sit-to-Stand Resistance Exercise for Children With Mild Spastic Diplegia: A Randomized Clinical Trial. Arch Phys Med Rehabil. 2007;88(1):25–31. Available from: https://doi.org/10.1016/j.apmr.2006.10.006

13. Sastroasmoro S. Dasar-dasar metodologi penelitian klinis. 5th ed. Jakarta: Sagung Seto; 2018.

14. Misdalia T, Moeliono MA, Idjradinata P. Pengaruh Latihan Duduk-Berdiri dengan Periodisasi Terhadap Gross Motor Function Measure Dimensi D dan E Cerebral Palsy Spastik Diplegia. Jakarta Indonesia Medical Association. 2012;62:397-401.

15. Gupta S, Rao BK, Kumaran SD. Effect of strength and balance training in children with Down syndrome: a randomized controlled trial. Clin Rehabil. 2011;25(5):425-32. Available from: https://doi.org/10.1177/0269215510382929

16. Artioli T. Understanding Obesity in Down's Syndrome Children. J Obes Metab. 2017;1(1):1–3.

17. Bertapelli F, Pitetti K, Agiovlasitis S, Guerra-Junior G. Overweight and obesity in children and adolescents with Down syndrome—prevalence, determinants, consequences, and interventions: a literature review. Res Dev Disabil. 2016;57:181-92.

18. Beqaj S, Tërshnjaku EET, Qorolli M, Zivkovic V. Contribution of Physical and Motor Characteristics to Functional Performance in Children and Adolescents with Down Syndrome: A Preliminary Study. Med Sci Monit Basic Res. 2018;24:159–67. Available from: https://doi.org/10.12659/MSMBR.910448

19. Maciałczyk-Paprocka K, Stawińska-Witoszyńska B, Kotwicki T, Sowińska A, Krzyżaniak A, Walkowiak J, Krzywińska-Wiewiorowska M. Prevalence of incorrect body posture in children and adolescents with overweight and obesity. Eur J Pediatr.

2017;176(5):563-72.

20. Artioli TO, Witsmiszyn E, Ferreira AB, Pinto CF. Assessing Down syndrome BMI and body composition. Int Med Rev Down Syndr. 2017;21(2):1-4. Available from: https://doi.org/10.1016/j.sdeng.2017.06.001

21. Aslan S, Aslan UB. An evaluation of fine and gross motor skills in adolescents with Down syndrome. Int J Sci Cult Sport. 2016;4(2):187-94. Available from: https://doi.org/10.14486/IntJSCS509

22. Melo GLR, Neto IVS, Fonseca EF, Stone W, Nascimento DC. Resistance training and Down syndrome: a narrative review on considerations for exercise prescription and safety. Front Physiol. 2022;13:948439. Available from: https://doi.org/10.3389/fphys.2022.948439

23. Imran S, Moeliono MA, Prabowo T. Loaded and unloaded sit-to-stand strengthening exercises effect to gross motor function measure in spastic diplegia cerebral palsy patients. Int J Integr Health Sci. 2016;4(1):8-14.

24. Vann CG, Haun CT, McKendry J, Roberts MD. Molecular and cellular mechanisms of skeletal muscle hypertrophy: a narrative review. Sports Med. 2023;53(8):1491-1512. Available from: https://doi.org/10.1007/s40279-023-01864-6

25. Jacinto M, Oliveira R, Brito JP, Martins AD, Matos R, Ferreira JP. Prescription and effects of strength training in individuals with intellectual disability: a systematic review. Sports. 2021;9(9):125. Available from: https://doi.org/10.3390/sports9090125

26. Bompa TO, Haff GG. Periodization: theory and methodology of training. 5th ed. Champaign, IL: Human Kinetics; 2009.

27. Volman MJM, Visser JJW, Lensvelt-Mulders GJLM. Functional status in 5 to 7-year-old children with Down syndrome in relation to motor ability and performance mental ability. Disabil Rehabil. 2007;29(1):25-31. Available from: https://doi.org/10.1080/09638280600947617

28. Galli M, Rigoldi C, Mainardi L, Tenore N, Onorati P, Albertini G. Postural control in patients with Down syndrome. Disabil Rehabil. 2008;30(17):1274-8. Available from: https://doi.org/10.1080/09638280701610353

29. Guzman-Muñoz EE, Gutierrez-Navarro LB, Miranda-Díaz SE. Neuromuscular features in children with Down syndrome. Int Med Rev Down Syndr. 2017;21(1):5-10. Available from: https://doi.org/10.1016/j.sdeng.2016.09.003