



## **THE EFFECT OF SENSORY-MOTOR VIRTUAL REALITY ON BALANCE IN CHILDREN WITH CLINICAL DOWN SYNDROME**

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### **ABSTRACT**

**Introduction:** Down syndrome affects approximately one in every 800 live births and leads to musculoskeletal disorders and motor skill delays. Children with down syndrome experience persistent deficits in balance and coordination. Virtual reality (VR) offers an interactive and immersive approach to therapy and has gained popularity in rehabilitation. This study explores the effect of sensory-motor virtual reality (VR SenMor) on static and dynamic balance in children with clinical down syndrome. **Methods:** A randomized controlled trial with a pre and post-test control group design was conducted with 20 children diagnosed with down syndrome. Treatment group (n = 10) received VR SenMor therapy twice a week for four weeks, while the control group (n = 10) received no treatment. Balance assessments were conducted using the pediatric balance scale (PBS) and timed up and go (TUG) test before and after the intervention. **Results:** There were no significant differences in age, gender, or BMI between the intervention and control groups. The VR SenMor therapy resulted in significant improvements in the PBS and TUG test scores in the intervention group compared to the control group. **Discussion:** VR SenMor therapy enhanced balance in children with down syndrome, with no confounding effects from age and gender. The VR system's sensory integration feedback and neuroplasticity mechanisms contributed to the improvements. The treatment's positive outcomes make it a promising approach for balance training at home. **Conclusion:** Sensory-motor virtual reality therapy shows promise in enhancing static and dynamic balance in children with clinical down syndrome.

**Keywords:** *sensory-motor virtual reality; down syndrome*

### **INTRODUCTION**

Down syndrome is a genetic disorder resulting from trisomy 21 chromosome abnormalities, occurring in approximately one in every 800 live births.<sup>1,2</sup> It often leads to musculoskeletal disorders like muscle hypotonia, decreased muscle strength, and hyperlaxity, which can cause developmental delays in motor skills.<sup>3,4</sup> Studies have shown that gross motor function improves in children with down syndrome as they age, but specific deficits in balance and coordination, associated with muscle tone and strength, persist.<sup>5</sup> Additionally, other abnormalities, such as ear infections, can also affect balance, limiting the independence of children and adolescents with down syndrome.<sup>5,6</sup>

Balance is influenced by the interaction of three systems: the visual, vestibular, and sensorimotor systems. Ayres explains that children with down syndrome may struggle with integrating sensory information into adaptive responses, affecting their judgments about the environment and how well they respond to challenges. Static standing balance deficits

are common in the down syndrome population, contributing to increased inactivity and poor posture control.<sup>6,7</sup>

Virtual reality (VR) is an interactive technology that can sense users' position and movement, providing sensory feedback and immersing them in a virtual environment with 3-dimensional images and animations. VR has gained popularity in rehabilitation during the pandemic, as it offers enjoyable and practical movements, motivating users, and enabling therapy at home. In this study, the researchers utilized sensory-motor virtual reality (VR SenMor) to stimulate activities aimed at improving sensory and motor functions. The VR SenMor system presents these activities in the form of a game set in a virtual world, making it a promising and accessible approach for children with down syndrome at home.

As research on virtual reality and balance deficits in children with down syndrome is still limited, the researchers conducted this study. This study differs from previous research by exploring a novel approach to virtual reality therapy for children



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with down syndrome. Its objective was to investigate the impact of sensorimotor virtual reality on the static and dynamic balance of children with clinical down syndrome.

## **METHODS**

This study utilized a randomized controlled trial with a pre and post-test control group design to investigate the effects of sensorimotor virtual reality therapy on children with clinical down syndrome. The research was conducted at *Rumah Pintar Pucang Gading* in February 2023. The total sample comprised 20 children who met specific inclusion criteria, such as having a clinical diagnosis of down syndrome, aged 9-18 years old, capable of independent standing and walking, able to follow instructions from researchers or caregivers, and with an IQ score between 55 and 69.

Certain individuals were excluded from the study, such as those with uncorrected visual disturbances, uncorrected hearing loss causing communication problems, vestibular disorders, high Conners Rating Scale score, and cardiac disorders. Participants who failed to adhere to the virtual reality therapy schedule or chose to discontinue their participation were categorized as dropouts.

The participants were divided into two groups: the treatment group, which received SenMor's VR therapy twice a week for four consecutive weeks, and the control group, which received no treatment.

The evaluation involved pre-treatment assessments of participants' balance levels using the pediatric balance scale (PBS) for static balance and the timed up and go (TUG) test for dynamic balance. Post-treatment evaluations were performed after the eighth therapy session using the same methods.

Statistical analysis included descriptive analysis and hypothesis testing. The normality of data distribution within the groups was examined using the Shapiro-Wilk test. For data with a normal distribution, the unpaired t-test was used for hypothesis testing, while data with abnormal distribution used the Mann-Whitney test. Within-group differences before and after treatment were analyzed using the paired t-test and Wilcoxon test for non-normally distributed data.

A p-value less than 0.05 with a 95% confidence interval was considered significant.

Data analysis was conducted using SPSS® software on a computer. Ethical clearance was obtained from the Ethics Commission of the Faculty of Medicine, Universitas Diponegoro, and Ungaran Hospital before conducting the research. Participants provided written informed consent and were informed about the research objectives, benefits, and potential effects. Participant data were kept confidential and would not be published without their permission. The researcher bore all the costs associated with the research.

## **RESULTS**

The research subjects were children aged 9-18 years old with down syndrome, who were members of the Indonesian Disabled People's Association Semarang branch and had completed 8 sessions of virtual reality training therapy. A total of 20 research subjects were included using the consecutive sampling method, where all individuals meeting the inclusion and exclusion criteria were randomly allocated to either the treatment or control group. The treatment group comprised 10 participants, as did the control group, with no dropouts, resulting in a total of 20 participants analyzed in the study.

Prior to commencing the research, socialization took place, and after obtaining informed consent, initial data collection was conducted. The treatment group underwent virtual reality training therapy eight times, with a frequency of two sessions per week lasting 20 minutes each, on Thursdays and Saturdays. The research was conducted in February 2023, and the final post-research data collection occurred on the last day of treatment.

The characteristics of the research subjects, including age, gender, and BMI, were recorded. Table 1 presents the test results for age, sex, and BMI in both the intervention and control groups, indicating no significant difference between the two groups. The participants' PBS scores were assessed before treatment, with the highest score being 52 and the lowest 17. After treatment, the highest PBS score was 56, and the lowest was 18. Regarding the TUG test,



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the highest time recorded before treatment was 17.12 seconds, and the shortest time was 11.27 seconds.

After treatment, the highest TUG time was 17.34 seconds, while the shortest time was 7.56 seconds.

**Table 1.** Characteristics of research subjects in the intervention and control groups

Variable	F	%	Mean ± SD*	Median (min – max)
Group				
Intervention	11	52,4		
Control	10	47,6		
Age			12,86 ± 3,20	12 (9 – 18)
Gender				
Male	14	66,7		
Female	7	33,3		
BMI*				
Underweight	2	9,5		
Normal	17	81,0		
Overweight	1	4,8		
Obese	1	4,8		
PBS* pre			33,24 ± 9,64	32 (17 – 52)
PBS* post			36,48 ± 10,88	35 (18 – 56)
TUG* pre			13,00 ± 1,34	12,56 (11,27 – 17,12)
TUG* post			11,12 ± 2,65	10,56 (7,56 – 17,34)

\*SD: Standard deviation, BMI: Body mass index, PBS: Pediatric balance scale, TUG: Timed up and go test

Balance was evaluated in both the intervention and control groups using the PBS. Table 2 displays the results of the paired difference test between pre-intervention PBS scores and post-intervention PBS scores in the intervention group, showing a significant difference. However, in the control group, there was no significant difference. The unpaired difference test between the intervention and control groups revealed significant differences in pre-intervention PBS scores, post-intervention PBS scores, and the difference in PBS scores.

Similarly, in Table 3, the paired difference test between the TUG test scores before and after treatment in the intervention group showed a significant difference, whereas in the control group, there was no significant difference. The unpaired difference test between the intervention and control groups indicated no significant difference in TUG scores before treatment. However, there were significant differences in TUG scores after treatment and the difference in TUG scores.

**Table 2.** PBS pre test, post test and delta scores

PBS	Group		p
	Intervention (11)	Control (10)	
Pre test	37,18 ± 9,87	28,90 ± 7,64	0,046 <sup>§*</sup>
Post test	43,18 ± 9,34	29,10 ± 7,11	<0,001 <sup>§*</sup>
p	<0,001 <sup>¶*</sup>	0,414 <sup>†</sup>	
Delta	6,00 ± 2,05	0,20 ± 0,79	<0,001 <sup>‡*</sup>

Note: \* Significant (p < 0,05); <sup>§</sup> Independent t; <sup>‡</sup> Mann Whitney; <sup>¶</sup> Paired t; <sup>†</sup> Wilcoxon

**Table 3.** TUG pre test, post test and delta scores

TUG	Group		p
	Intervention (10)	Control (10)	
Pre test	12,57 ± 0,99	13,48 ± 1,55	0,123 <sup>§</sup>
Post test	8,96 ± 0,91	13,50 ± 1,62	<0,001 <sup>§*</sup>
p	<0,001 <sup>¶*</sup>	0,944 <sup>†</sup>	
Delta	-3,61 ± 0,83	0,02 ± 0,08	<0,001 <sup>‡*</sup>

Note: \* Significant (p < 0,05); <sup>§</sup> Independent t; <sup>‡</sup> Mann Whitney; <sup>¶</sup> Paired t; <sup>†</sup> Wilcoxon



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In summary, the PBS showed significant improvements after intervention in the intervention group compared to the control group. Similarly, the TUG test demonstrated significant improvements after treatment in the intervention group compared to the control group.

## DISCUSSION

The research subjects were children aged 9-18 years with down syndrome, and their characteristics included age, sex, and BMI. Statistical analysis indicated that there were no significant differences in mean age ( $p = 0.070$ ) and gender ( $p = 0.221$ ) between the intervention and control groups, suggesting that age and sex were not confounding factors in the study. This finding aligns with previous research by Rahman *et al.*, which also reported no significant differences in age and gender among participants.<sup>8</sup> However, there was no significant difference in BMI in this study, as the intervention group had normal BMI. Contrarily, other studies have shown that BMI with obesity can impact balance due to increased burden on muscles, bones, and joints, leading to disturbed musculoskeletal function and posture changes.<sup>9</sup>

The statistical tests for static and dynamic balance demonstrated an increase in balance in children with clinical down syndrome. This finding is supported by previous studies that have shown the benefits of using virtual reality for balance training in non-disabled individuals. For instance, Song *et al.* found that virtual reality balance training through static cycling in a virtual environment improved postural balance via visual feedback mechanisms.<sup>10</sup> The SenMor virtual reality used in this study offers two levels of activities, such as walking in the park and searching for coins, which provide sensory integration feedback (visual, proprioceptive, and vestibular) and stimulate neuroplasticity, leading to improved balance and postural control.

In the study, two different types of glasses/goggles were used, including a small 3D biconvex lens with a cardboard cell phone holder, which was specifically used for two children with microcephaly. This specialized equipment did not affect the research outcomes but provided additional

benefits in terms of balance improvement after engaging in SenMor virtual reality exercises.

During the study, there were no dropouts among the children, and one child experienced dizziness on the second day of the first week but recovered after a 10-minute rest. The cognitive abilities of the children ranged from 55 to 68, categorized as educable, which indicates that IQ levels did not act as confounding factors.

Selective motor posture control loss in children with down syndrome can disrupt balance function due to associated musculoskeletal disorders like hypotonia, muscle weakness, or joint laxity. The sensory-motor virtual reality used in the study is not a standalone treatment but a combination of physical and occupational therapy, serving as a home program to enhance selective motor control and improve gross motor skills that influence balance.<sup>10-12</sup>

Previous research studies have also demonstrated the positive impact of virtual reality on balance and postural control in various neurological conditions. For example, Deutsch *et al.* reported an increase in postural control after using VR-Wii in subjects with neurological disorders, indicating improved stability in posture and balance.<sup>13</sup> Virtual reality training has shown benefits in maintaining balance by stimulating the vestibular and proprioceptive systems, as observed in studies on children with cerebral palsy by Shumway-Cook *et al.* and post-stroke patients by Walker *et al.*<sup>13,14</sup>

The repetitive movements and multisensory feedback provided by virtual reality systems contribute to the improvement of balance and cognition through neural plasticity mechanisms, as supported by study by Ribeiro *et al.*, virtual reality has proven to be a valuable tool in enhancing motor coordination and balance by engaging the brain's neuroplasticity mechanism.<sup>16</sup>

## CONCLUSION

There are observed variations in the impact of SenMor virtual reality on static and dynamic balance in children with clinical down syndrome following the SenMor virtual reality intervention between the treatment and control groups. Virtual Reality exercises



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present a viable alternative for enhancing balance. In summary, SenMor virtual reality therapy exhibits potential for improving both static and dynamic balance among children diagnosed with down syndrome. Future research could explore its effectiveness on subjects with diverse medical conditions and compare it with traditional physical exercises.

### ETHICAL APPROVAL

The research was conducted after obtaining ethical clearance from the Ethics Committee in Health and Medical Research Faculty of Medicine, Universitas Diponegoro, Semarang, with no. 1357/EC/KEPK-RSDK/2022.

### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### FUNDING

No specific funding was provided for this article.

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## JURNAL KEDOKTERAN DIPONEGORO (DIPONEGORO MEDICAL JOURNAL)

Online : <http://ejournal3.undip.ac.id/index.php/medico>

E-ISSN : 2540-8844

DOI : [10.14710/dmj.v13i2.42137](https://doi.org/10.14710/dmj.v13i2.42137)

JKD (DMJ), Volume 13, Number 2, March 2024 : 66-71

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