



COMBINATION OF VESTIBULAR STIMULATION AND PERCEPTUAL MOTOR PROGRAM COULD IMPROVE BALANCE IN CHILDREN WITH FLAT FOOT

KOMBINASI VESTIBULAR STIMULATION DAN PERCEPTUAL MOTOR PROGRAM DAPAT MENINGKATKAN KESEIMBANGAN PADA ANAK DENGAN FLAT FOOT

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ABSTRACT

Background: Flat foot is a common lower extremity deformity in children. Underdeveloped arches can lead to complaints such as fatigue during prolonged walking, impaired balance, frequent injuries, and pain. Several interventions can be employed to address these issues, including arch muscle strength exercises, toe curls exercises, calf stretches, and plantar fascia stretches. **Purpose:** This study aims to prove the effectiveness of a combination of heel raises exercise and vestibular stimulation versus a combination of heel raises exercise and perceptual motor program in increasing lower extremity muscle strength and standing balance in children with flat foot. **Method:** This research is a quasi-experimental study that utilized a pre-test and post-test two-group design with a purposive sampling method. A total of 30 subjects were put into 2 groups. Group 1 received a combination of heel raise exercises and vestibular stimulation. Group 2 received a combination of heel raise exercise and perceptual motor program. Lower extremity muscle strength was assessed using the Manual Muscle Test (MMT), and standing balance was evaluated using the Pediatric Balance Scale (PBS). **Result:** Both groups showed differences in the measurement aspects of MMT and PBS (p -value < 0.05). However, no significant difference was found between the groups in the MMT score. In contrast, a significant difference was observed in PBS scores, with Group 2 demonstrating greater improvement (p -value < 0.05). **Conclusion:** The combination of heel raises exercise and a perceptual motor program is more effective in improving balance in children with flat foot compared to the combination with vestibular stimulation.

ABSTRAK

Latar belakang: Deformitas ekstremitas bawah yang sering terjadi pada anak adalah *flat foot*. Lengkungan yang tidak tumbuh normal biasanya menimbulkan keluhan kelelahan saat berjalan dalam waktu lama, gangguan keseimbangan, cedera berlebihan, dan nyeri. Ada beberapa pelatihan yang biasanya digunakan, diantaranya *arch muscle strength exercises*, *toe curls exercises*, *calf stretches*, dan *plantar fascia stretches*. **Tujuan:** Penelitian ini bertujuan untuk membuktikan efektivitas kombinasi latihan *heel raises* dan stimulasi vestibular dibandingkan kombinasi latihan *heel raises* dan program perceptual motor dalam meningkatkan kekuatan otot ekstremitas bawah dan keseimbangan berdiri pada anak dengan *flat foot*. **Metode:** Penelitian quasi-eksperimen dengan desain *pre-test*, *post-test two group design*, dan pengumpulan sampel menggunakan metode *purposive sampling*. 30 subjek dibagi menjadi 2 kelompok. Kelompok 1 diberikan kombinasi latihan *heel raise exercise* dan *vestibular stimulation*. Kelompok 2 diberikan kombinasi latihan *heel raise exercise* dan *perceptual motor program*. Penelitian ini mengevaluasi kekuatan otot ekstremitas bawah yang diukur dengan *Manual Muscle Test* (MMT) dan keseimbangan berdiri anak yang diukur dengan *Pediatric Balance Scale* (PBS). **Hasil:** Terdapat perbedaan tiap kelompok pada aspek pengukuran MMT dan PBS (p -value < 0,05). Namun, tidak terdapat perbedaan antar kelompok jika dibandingkan nilai MMT, sedangkan pada nilai PBS terdapat perbedaan yang signifikan antar kelompok (p -value < 0,05). **Kesimpulan:** Kombinasi latihan *heel raises* dan program *perceptual motor* lebih baik dalam meningkatkan keseimbangan anak dengan *flat foot*.

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INTRODUCTION

The rapid development of technology in Indonesia has contributed to a decline in physical activities and changes in lifestyle, leading to health problems. This trend is not limited to adults, but is also evident in children. Many children at present prefer sedentary activities such as playing with gadgets at home, which results in limited physical movement. Over time, it could affect their physical structure and function (Amrnyia and Prameswari, 2022).

The lower extremities are one part of the limbs that is very important for performing various physical activities and sports. The lower extremity is a special region that performs two different functions, namely providing balance and generating power (Sahri *et al.*, 2017). To support these two functions, one part of the lower extremity, namely the plantar, contains an arch formed by a combination of bone structure, aponeurosis, ligaments, and tendons (Sharma and Upadhyaya, 2016).

The arch plays an important role in the biomechanics of the lower extremities by enhancing stability during standing, stepping, evenly distributing weight on the feet, increasing speed and agility while walking, and supporting balance and flexibility. (Kodithuwakku Arachchige *et al.*, 2019; Witari *et al.*, 2018). There are types of arches, namely the medial longitudinal arch, lateral longitudinal arch, and anterior transverse arch (Sharma and Upadhyaya, 2016). Biomechanically, even minor changes in the plantar structure, particularly in the arch, can lead to reduced support, deformity, and impaired balance function. (Hazzaa *et al.*, 2015).

Deformities of the lower extremities are common in children, with the flat foot being one of the most frequently encountered conditions. In fact, up to 90% of clinical visits for related complaints are due to flat foot. It is considered normal for children under the age of three to have flat feet, as the foot arch typically begins to develop after this age (Sahri *et al.*, 2017). A study conducted in India in 2014 reported that 11.25% of individuals aged 18 - 25 years had bilateral flat feet. In Taiwan, it was also reported that the prevalence of pes planus in children aged 6 - 12 years was 13.88%. Meanwhile, a study on flat foot in Indonesia reported that 24.14% of boys aged 8 - 12 years and 17.24% of girls had flat feet (Witari *et al.*, 2018).

A study conducted by Jaya *et al.* (2022) on elementary school children aged 7 - 12 years old at the Cipta Dharma Denpasar School in 2020 found that 496 students had flat feet (53.3%). The majority of the participants involved in the study were 502 male students (53.9%). Most of the participants were in the 7 and 11-year-old age groups, comprising 163 students (17.5%) and 173 students (18.6%), respectively. In addition, research conducted by Paramasti *et al.* (2023). In Denpasar City, it was reported that the prevalence of flat foot was 49 people out of 62 students who were classified (79%) as overweight or obese.

Foot deformity in the form of a flat foot can lead to long-term pain in the soles of the foot ankles, and knees. It may also cause recurrent acute trauma that worsens foot deformity. Foot deformities occur due to disruptions in the development of the foot arch, specifically when the medial longitudinal arch is reduced or absent. Flexible flat foot is a condition that is mostly caused by physiological factors and does not require surgical intervention. Normally, the foot arch develops within the first five years of life, typically between the ages of 2 - 6 years (Damayanti *et al.*, 2018). The arch of the foot plays an important role in absorbing ground reaction forces and supporting body weight during physical activities. Changes in the structure of the foot arch of the foot cause biomechanical changes in the lower extremities (Sung, 2016). The height of the arch is also a risk factor for lower extremity injuries and musculoskeletal pain. Foot and ankle muscle strength plays an important role in supporting the arch structure of the foot and increasing movement initiation (Sativani and Pahlawi, 2020).

Changes in posture caused by flat foot can lead to decreased functional ability and performance of the foot and ankle, reduced elasticity in ligaments and muscles, and alterations in the body's Center of Gravity (COG). Ligaments, muscles, range of motion, and COG are essential for effective body movements. Body movements are a critical means by which children interact with their environment. Postural balance serves as the foundation for coordinated movement and is defined as the integration of sensorimotor systems that help maintain body posture within normal limits. Postural control and stability are influenced by the visual, vestibular, and proprioceptive systems. During childhood, increased patterns of postural control over daily activities experience a peak of maturation for the proprioceptive system between the ages of 3 - 4 years. The visual and vestibular systems achieve peak maturation at age 15 or 16 years (Sativani and Pahlawi, 2020).

During the weight-bearing activities, flat feet position the foot in plantar flexion and adduction of the talus along with valgus of the calcaneus. These structural changes in the lower limbs alter the transmission of sensory information, which will affect muscle activation to maintain body posture. The reduction in foot function leads to increased performance demands on both intrinsic and extrinsic foot muscles as a compensatory to maintain postural stability and a balanced stance of the feet during walking, which is one of the most important activities of human beings (Güler *et al.*, 2020; Pekiavas *et al.*, 2022).

The foot has two primary functions at the time of locomotion, i.e., stance and propulsion. Stance and propulsion are the main functions of the legs during the locomotion process. The intrinsic foot muscle provides firmness and stability for propulsion, while flexibility for shock absorption and attenuation of forces. Improper function of the intrinsic foot muscles caused an excessively pronated foot (Khisty *et al.*, 2022). The

foot has been considered both as an elastic mechanism that increases the efficiency of locomotion by recycling energy, as well as an energy sink that helps stabilize movement by dissipating energy through contact with the ground (Riddick *et al.*, 2019).

Several types of exercises can be implemented to address flat foot, including: arch muscle strengthening, toe curls, calf stretches, and plantar fascia stretches. However, these interventions alone have not provided significant improvements in balance, especially dynamic balance. It needs to be complemented by interventions to enhance sensory input, such as proprioceptive and vestibular input. One therapeutic modality that can be applied to improve strength and balance in individuals with flat feet is the heel raises exercise, which targets muscle strength in the anterior tibialis area (Aktifah *et al.*, 2021). This can be combined with an exercise program that focuses more on stimulating somatosensory input, namely vestibular stimulation and perceptual motor programs (Parashar *et al.*, 2017).

This study aims to (1) Examine the effectiveness of heel raises exercise combined with vestibular stimulation in increasing lower extremity strength and standing balance in children with flat foot. (2) Investigate whether the combination of heel raises exercise and perceptual motor programs can improve lower extremity strength and standing balance in children with flat foot. (3) Compare the effectiveness between the combination of heel raises exercise and vestibular stimulation versus the combination of heel raises exercise and the perceptual motor program in improving lower extremity strength and standing balance in children with flat foot.

MATERIAL AND METHOD

This study employed a quasi-experimental design with a pre-test and post-test. Participants were recruited using a purposive sampling method. A total of 30 participants were put into 2 groups. Group 1 received a combination of heel raises exercise and vestibular stimulation. Group 2 received a combination of heel raises exercise and a perceptual motor program. The research was conducted at private clinics specializing in the growth and development of children with special needs in Denpasar and Badung from July to August 2023. The participants in the study were children aged 6 - 12 years old with flexible flat foot through physical examinations. Eligibility criteria include the ability to stand and walk independently, the absence of visual and hearing impairment, and the ability to follow instructions.

The classification of flat foot grade uses the footprint test method, which involves several media such as colored ink and white paper. The procedure began with the participant placing their foot in colored ink, followed by stepping onto a sheet of white paper

to create a footprint impression. This footprint was then analyzed to determine the flat foot grade using Clarke's angle. Clarke's angle is obtained by drawing a line between the medial side of the head of the first metatarsal and the heel and a line between the head of the first metatarsal and the top of the longitudinal medial arch so that a tangent angle is formed. Based on Clarke's angle, flat foot in children aged 3 to 17 years is classified into three grades, namely (1) Grade 1, angle between 35° and 42°, (2) Grade 2, angle between 30° and 34.9°, and (3) Grade 3, angle of $\leq 29.9^\circ$ (Pita-Fernández *et al.*, 2015).

Children who experienced pain, neurological disorders, or lower extremity dysfunction, recent surgical procedures for deformity correction, soft tissue release, and regular participation in sports activities were excluded from the study. The drop-out criteria include: failure to attend two consecutive therapy sessions, occurrences of injury during the course of the study, and deterioration of the participant's condition during the course of the study.

The inclusion criteria specified that participants did not use an orthosis and were diagnosed with flexible flat feet. The characteristic of a flexible flat foot is the appearance of a flat arch structure during weight-bearing processes such as standing and walking, and the arch is more visible when the foot is in a non-weight-bearing position, for example, in a sitting position. This condition may arise due to several possibilities, including recurrent injuries or trauma to the feet and ankles, altered alignment, such as deformities in the feet, spine, pelvis, or lower extremities (Mahendrayani and Yoda, 2022). The generally accepted explanation of flexible flat foot is the excessively flexible arch often associated with hypermobility of the subtalar joint. Flexible flat foot is a condition that is mostly caused by physiological factors and does not require medical intervention (Ueki *et al.*, 2019).

Sample recruitment was carried out purposively, namely looking for criteria for children with a flat foot condition by taking into account the degree/level of flat foot. These 30 participants were recruited because they met the predetermined criteria and were willing to fill out informed consent as samples/research subjects. To minimize potential bias, age homogeneity was maintained across the sample to ensure comparable baseline characteristics. Additionally, field assistant physiotherapists involved in the intervention received prior training sessions to standardize procedures.

Heel raise exercise illustrated in Figure 1 was conducted through the following steps, namely (1) The child stands barefoot, (2) The child lifts both heels to stand on tiptoe, focusing on the contraction of the tibialis anterior area, (3) The child holds the position for a count of 30 seconds, and (4) repeats the movement 10 times (Ueki *et al.*, 2019).



Figure 1. Heel raise exercise

The vestibular stimulation as illustrated in Figure 2 is carried out by (1) Spinning, the child is asked to sit on a hammock/swiss ball, which is then rotated 10 times to the right and 10 times to the left, (2) Sliding, the child is asked to lie on his back on a large roller pillow, which is then rolled quickly backwards and forwards 10 times, with the therapist holding both of the child's legs, (3) Bouncing up and down, still on the roller, the child is asked to sit, the therapist holds the child's pelvis then performs vertical bouncing movements up and down for 5 minutes with a total duration of 10 minutes (Parashar *et al.*, 2017).



Figure 2. Vestibular stimulation exercise

The perceptual motor program as illustrated in Figure 3 is carried out by (1) Positioning the child to stand on the evamat, (2) Giving instructions and examples of movements for the child to take a position with one leg moving forward and backward in each movement with a count of 10 seconds alternately, (3) Performing movements with patterned jumps forward, (4) Continuing walking on the footbridge with dimensions of 2.5 meters long, 7 cm wide, and 10 cm

high by walking forward slowly, and (5) Repeating the entire sequence 10 times within a 30 minute session (Maryatun, 2012; Yudanto, 2023).



Figure 3. Perceptual motor program

This study evaluates lower extremity muscle strength using the Manual Muscle Test (MMT) and assesses the child's standing balance using the Pediatric Balance Scale (PBS). The MMT is performed based on the criteria of 'Muscle Testing Daniels and Worthington: Techniques of Manual Examination and Performance Testing' (Arti and Widanti, 2023).

The measurement steps are as follows, namely (1) Explain the purpose and procedure to the patient, (2) Position the patient in a position against gravity, (3) Stabilize the proximal joint, (4) Instruct the patient to move the distal segment of the joint passively within a range of motion, (5) Return the distal segment to initial position for starting position, (6) Palpate the tested muscle while maintaining stabilization in the proximal joint, and (7) Ask the patient to perform movements within the ROM that are possible actively (Arti and Widanti, 2023).

In the assessment of the lower extremities, include the following steps namely (1) Check knee extension by placing the examiner's hand under the knee and ankle, ask the patient to extend the knee against the examiner's resistance, and compare with the contralateral side. This test evaluates the quadriceps femoris, and knee extension by the quadriceps muscle and innervated by L3 and 4 via nerve femoris, and (2) Check knee flexion by holding the knee and applying resistance to the ankle, ask the patient to pull the heel towards the buttocks as hard as possible (flexion) against the examiner's resistance, compare with the contra lateral side. This test checks the hamstring muscles innervated by L5 and S1 via nerve sciatica (Arti and Widanti, 2023). The collected data were analyzed using (1) Normality test, (2) Comparative analysis, and (3) Difference test. Data analysis is used to examine differences in disability between the two intervention groups.

RESULT

The number of subjects participating in this research was 30 participants (Table 1), with a total of 15 children in each group. The results of the descriptive test are revealed. The average age of the participants was 7.9 ± 1.5 in Group 1. The descriptive test also demonstrated that the average age in Group 2 was 8.5 ± 1.8 .

Based on the results of the normality test in Table 2, it shows that all pre-and post-test data measured with MMT in both Groups 1 and 2 yielded a p -value < 0.05 , indicating that the data were not normally distributed. The hypothesis testing used is a non-parametric test. In contrast to the pre-and post-test data with lower extremity muscle strength measurements in Groups 1 and 2 in PBS, the p -value was (p -value > 0.05), except

for the pre-test data in Group 2 and post-test data in Group 1. This indicates that the data were not normally distributed in Group 1 and Group 2. The hypothesis test used is a non-parametric test.

The results of the hypothesis test in Table 3 show that Group 1 and Group 2 obtained (p -value < 0.05). This shows that there is a significant difference after giving the intervention in each group as measured by MMT and PBS. Based on Table 4, the results of hypothesis testing using the Mann-whitney U-test stated that there is no significant difference between Group 1 and Group 2 (p -value > 0.05) in the variable of MMT, but there is a significant difference in PBS measurements, where better improvement was shown in Group 2, with median $\pm$ IQR: 48 ± 3.00 .

Table 1. Age and gender differences between two groups

Group	Gender		Age
	Male	Female	
Group 1	7 (46.7%)	8 (53.3%)	7.9 ± 1.5
Group 2	6 (40.0%)	9 (60.0%)	8.5 ± 1.8

Group 1: participants who received a combination of heel raises exercise and vestibular stimulation. Group 2: participants who received a combination of heel raises exercise and a perceptual motor program

Table 2. Data normality test results

Variabels	Group 1 (p-value)	Group 2 (p-value)
Manual Muscle Testing (MMT)		
Pre - test	0.001	0.001
Post - test	0.001	0.001
Pediatric Balance Scale (PBS)		
Pre - test	0.058	0.012
Post - test	0.002	0.059

Group 1: participants who received a combination of heel raises exercise and vestibular stimulation. Group 2: participants who received a combination of heel raises exercise and a perceptual motor program

Table 3. Difference test results before and after treatment in each group

Variabels	Group	Before intervention		After intervention		p-value
		Median	IQR	Median	IQR	
Manual Muscle Testing (MMT)	Group 1a	4.00	1.00	5.00	00.00	0.008*
	Group 2a	4.00	1.00	5.00	1.00	0.014*
Pediatric Balance Scale (PBS)	Group 1a	42.00	4.00	45.00	3.00	0.001*
	Group 2a	43.00	3.00	48.00	3.00	0.001*

^aWilcoxon signed-rank test, *(p -value < 0.05). Group 1: participants who received a combination of heel raises exercise and vestibular stimulation. Group 2: participants who received a combination of heel raises exercise and a perceptual motor program

Table 4. Difference test results before and after treatment between group

Variabels	Grup data	Median $\pm$ IQR	p-value
Pre-test ^a (Manual Muscle Testing (MMT))	Group 1	4.00 $\pm$ 1.00	1.000
	Group 2	4.00 $\pm$ 1.00	
Post-test ^a (Manual Muscle Testing (MMT))	Group 1	5.00 $\pm$ 0.00	0.775
	Group 2	5.00 $\pm$ 1.00	
Pre-test ^a (Pediatic Balance Scale (PBS))	Group 1	42.00 $\pm$ 4.00	0.902
	Group 2	43.00 $\pm$ 3.00	
Post-test ^a (Pediatic Balance Scale (PBS))	Group 1	45.00 $\pm$ 3.00	0.016*
	Group 2	48.00 $\pm$ 3.00	

^aMann-whitney U-test, *p-value < 0.05. Group 1: participants who received a combination of heel raises exercise and vestibular stimulation. Group 2: participants who received a combination of heel raises exercise and a perceptual motor program

DISCUSSION

The prevalence figures of flat foot remain relatively high among children. This can be caused by internal or external factors in the child. The condition of flat foot in children is generally a flexible flat foot condition, which still has a good prognosis if treated correctly and quickly, and the symptoms will disappear as they get older. Flat feet are generally not considered dangerous as long as the child or individual does not feel several symptoms, such as stiffness and severe pain in the foot area. Previous studies have indicated that flat foot occurs as an accumulation of alignment changes in the structure of the bones, muscles, and ligaments in the feet (Fatimah and Nesi, 2022). Basically, humans are born with flexible flat feet, and normal foot arches develop in the first decade of life (Taha and Feldman, 2015).

The results of the study demonstrated that the combination of the heel raise exercise and vestibular stimulation could improve lower extremity muscle strength and standing balance in children with flat foot. This can also be seen in the combination of heel raise exercise and perceptual motor programs. Heel raises exercise is a static exercise that involves the stabilizing muscles that form the arch of the foot. Strengthening the gastrocnemius muscle is achieved by performing heel raises with straight legs, lifting the heels into tiptoe. Heel raises exercise has a positive impact on the nerves and skeleton due to proprioceptive stimulation to maintain a balanced position (Ueki *et al.*, 2019). Other research, which uses a combination of heel raises exercise and tightrope walker, is in line that the combination of the exercise could improve dynamic balance in children with dynamic balance (Herawati, 2019). Heel raise exercise can improve static balance, where repeated tiptoeing can cause the gastrocnemius and plantaris muscles to contract; with this contraction, muscle strength will

increase. The brain will be stimulated when disturbances occur from outside the COG, the line of gravity and base of support from the body will be activated to be able to maintain body position (Herawati, 2019).

This study is further supported by previous research where researchers used vestibular stimulation in children with Cerebral Palsy (CP) and showed a significant improvement in standing balance. This occurs because the vestibular system integrates all other functional systems, which stimulates postnatal development of the Central Nervous System (CNS) (Nahla *et al.*, 2022). The CNS determines the normalization of motor development, speech, and cognitive development (Herssens and McCrum, 2019).

Heel raise exercise can improve static balance as repeated tiptoeing activates the gastrocnemius and plantaris muscles to contract with this contraction, muscle strength will increase. The brain stimulates when disturbances occur from outside the COG, line of gravity, and base of support from the body that will be activated to maintain body position (Ueki *et al.*, 2019). Heel raises exercise is a static exercise that involves the stabilizing muscles that form the arch of the foot. To strengthen the gastrocnemius, the exercise involves keeping the legs straight and raising into tiptoe. Heel raises exercise has a positive impact on the nerves and skeleton due to proprioceptive stimulation to maintain a balanced position (Meisatama *et al.*, 2022).

Vestibular stimulation targets somatosensory system input to enhance balance. This finding is also supported by previous research, where vestibular stimulation was applied to children with cerebral palsy and showed a significant improvement in standing balance. This occurs because the vestibular system integrates all other functional systems, which stimulates postnatal development of the CNS. The CNS determines the normalization of motor development, speech,

and cognitive development, with repeated vestibular stimulation, a neuroplasticity process occurs, where the activation of inactive synapses becomes active. Vestibular stimulation over time can improve sensory integration and balance in individuals with cerebral palsy. Vestibular stimulation can increase levels of playfulness, visual exploration behavior, motor and balance development, and reflex integration in at-risk children and children with developmental delay disorders (Parashar *et al.*, 2017).

Other studies on Perceptual Motor Program (PMP) training show that it can support the development of the nervous system in the brain and enhance children's abilities, particularly in processing sensory input (visual, auditory, tactile, and kinesthetic), integrating sensory information, interpreting motor responses, engaging in movement activities, and transmitting stimuli to the brain (Maryatun, 2012; Yudanto and Alim, 2021). PMP is an organized sequence of program activities aimed at developing visual, auditory, verbal, tactile, and kinesthetic perception through the use of motor skills and children's understanding of themselves in relation to their world, through movement experiences (Maryatun, 2012; Xu *et al.*, 2022).

The result of perceptual motor and reaction will produce movement. The activities in this program require children to engage both left and right hemispheres of the brain. Previous research on children with autism spectrum disorder showed that the effect of PMP on balance, stating that the PMP increased static balance by 36.18% and dynamic balance by 124.59% (Pramita *et al.*, 2022). The perceptual motor program has demonstrated that coordination training can enhance both extremity strength and balance, both static and dynamic. Static and dynamic balance, as well as the ability to maintain standing balance and perform hand coordination, are associated with the sensitivity of the eyes, ears, and mouth by providing perceptual motor training. This program effectively improves standing balance (Widiantara *et al.*, 2020).

Heel raises exercise combined with a perceptual motor program aims to improve lower extremity strength and somatosensory system input (Meisatama *et al.*, 2022). The heel raise movement involves increasing the muscles of the lower legs and feet (Meisatama *et al.*, 2022) while PMP enhances input from the somatosensory system, thereby forming work integration between the sensory and motor systems (Widiantara *et al.*, 2020). Combining heel raises with toe curls contributes to improving the foot arch and strengthening leg muscles such as the gastrocnemius, thereby supporting balance (Meisatama *et al.*, 2022; Widiantara *et al.*, 2020). This research has limitations, particularly in not controlling the levels of physical activity or sports activity in children. Further research

is recommended to determine the optimal training dosage to improve muscle strength in children with flat foot.

CONCLUSION

The combination of heel raises exercises and vestibular stimulation is as good as the combination of heel raise exercises and the perceptual motor program in increasing lower extremity muscle strength. However, the combination of heel raised exercises and perceptual motor program demonstrates greater effectiveness in improving balance in children with flat foot.

It is hoped that the combination of heel raise exercises and perceptual motor program can be applied as an alternative to improve balance in children with flat foot. Meanwhile, further research is needed regarding the appropriate training dosage to increase muscle strength in children with flat foot.

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AUTHOR CONTRIBUTION

The idea for this study was initiated by N. L. P. G. K. S. after conducting a preliminary study and a literature review related to the variables in the research. After establishing the idea and determining the research variables, N. L. P. G. K. S. and M. H. S. N. designed the research methodology, which included the study design, preparation for sample recruitment, research permits, and preparation of research facilities and infrastructure. P. M. K. and A. A. N. T. N. D. conducted follow-up activities related to the intervention process as well as data collection before and after the intervention was administered. In the final stage, all authors discussed the results and contributed to the final manuscript.

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DATA AVAILABILITY

The datasets generated and/or analysed during the current study are not publicly available due to as stated and agreed upon in the informed consent, there is a confidentiality agreement between the researchers and the subjects regarding patient data, but are available from the corresponding author on reasonable request.

CONFLICT OF INTEREST

The authors state there is no conflict of interest with the parties involved in this study.

ETHICAL APPROVAL

This research has been approved by the Ethics Committee Unit of the Faculty of Medicine, Universitas Udayana, with number: 2170/UN 14.2.2.VII.14/LT/2023, issued on September 19th, 2023.

INFORMED CONSENT

This manuscript contains individual data, and each individual data presented in the manuscript has obtained publication consent through the signing of an informed consent form.

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