



Effect of Foot Muscle Strengthening to Increase Dynamic Balance in Children with Flexible Flatfoot

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Abstract. Balance or postural stability, defined as the ability to keep the center of gravity above the base of support. Dynamic balance is a movement system that functions to control and maintain body position involving the neuromuscular, musculoskeletal and cognitive systems with changes from the center of gravity. The dynamic balance of children is determined by coordinated activities between the nervous system, muscles, brain and spinal cord. Flexible flatfoot conditions in children can interfere with daily activities, especially in sports activities. Flexible flatfoot is a condition where the sole of the foot is flat caused by the loss of the medial longitudinal arch when standing. This study aims to determine the effect of foot muscle strengthening on improving dynamic balance in children with flexible flatfoot. Method: This research was an experimental study with one group pre-test post-test design. The subjects 13 people who were given foot muscle strengthening intervention. Subjects were given treatment 3 times a week for 6 weeks. Sampling used a technique with random sampling. The balance beam walking test is used to measure dynamic balance and the wet foot print test is used to measure flexible flatfoot. Result: Subjects who were given the intervention obtained the average difference in dynamic balance before the intervention of 1.46 ± 0.776 and after the intervention of 2.62 ± 0.870 with a p value of 0.001. Conclusion: Foot muscle strengthening effect can improve dynamic balance in flexible flatfoot. Suggestion: Foot muscle strengthening can be used as a physiotherapy intervention to improve dynamic balance in children with flexible flatfoot.

Keywords: Dynamic Balance · Foot Muscle Strengthening · Flexible Flatfoot · Foot Muscle Strengthening · Wet Foot Print Test · Balance Beam Walking Test

1 Introduction

Balance is an important component in motor activity and postural control which is an important factor of physical fitness which is examined statically and dynamically. The ability of postural control to maintain balance in a gravitational field through continuity or return to a center of gravity located outside the body. Postural control is the complex coordination of sensory information and biomechanical activity and muscle

activity against external forces. Loss of each of these factors can increase postural swing and reduce the ability to maintain control of part or all of the body in sports activities, somatic-sensory system, visual system, vestibular system and muscle activity involved in maintaining postural and cognitive control [1]. Disorders that can cause walking barriers are flatfoot [2]. Flexible flatfoot is caused by many reasons such as tibialis posterior dysfunction, abnormalities of the foot bones, ligament laxity, shortened Achilles tendon, calf muscle tightness or contracture, and weakness of the foot muscles. Flatfoot, pes planus or fallen arch is a common disorder that arises from a decrease of the medial longitudinal arch. This deformity induces calcaneus bone in the valgus position and talus bone in plantar flexion with adduction producing excessive pronation of the foot when bearing full weight. Flexible flatfoot is a condition in which the arch is flat while standing during weight bearing and the arch appears during non-weight bearing. Flatfoot is a form of flat feet caused by the arches of the bones becoming flatter; this can occur due to injuries to the feet and ankles or arise due to balance disorders that occur due to traumatic causes or changes in body posture such as on deformities (changes in shape) of the spine, pelvis or lower limbs. Foot-muscle training can reduce over pronation, assist in restructuring the foot, is easy to perform, cost-free, and provides long-term effect. However, it requires time to improve symptoms and must be performed continuously and consistently. Treatment techniques for flatfoot include taping, orthoses, shoe modification, surgery, and foot muscle exercise. Taping, orthoses and shoe modification are conservative treatments that provide short-term effects and do not adjust foot structure. Surgery can improve pain, function, and foot alignment but is vulnerable to complications after surgery and requires time for recovery. Children who have flatfoot need to get attention from parents, so that the problem can be identified early on and the appropriate therapy can be given immediately. Actively moving, playing and doing activities require optimal support for limb function and coordination [3]. In 90% of the children aged <2 years, an anatomic variation resembling flatfoot can be seen which is due to infantile adipose cushion formation localized on the medial part of the foot. Besides toddlers who start to walk can assume a flatfoot posture. In fact they try to walk with their feet resting entirely on the ground so as to maintain a balanced posture. Consequently, they shift their weight-bearing axis to the first or second tarsometatarsal joint which may induce a flatfoot posture. In most of the children normal longitudinal arch develops at 3–5 years of age, and in only 4% of them flatfoot persists after 10 years of age. Foot bones supported with ligaments, tendons, and capsular structures form the normal medial longitudinal arch of the foot. Foot muscles do not maintain longitudinal arch. Electromyographic (EMG) studies have revealed that neither intrinsic, nor extrinsic muscles support, and maintain longitudinal arches at standing posture [19]. However during walking, and activities performed, both muscle groups maintain dynamic stabilization of the arch. In a study reinforcing this argument. In recent studies, flatfoot seen in posterior tibial tendon insufficiency which has been studied extensively, suggests the importance of this musculature. In their biomechanical study plantar fascia is the most important anatomical structure contributing to the stability of the medial arch, followed by talonavicular, and spring ligaments [11]. Therefore, to improve dynamic balance in flexible flatfoot, foot muscle strengthening intervention is needed. Foot muscle strengthening is a strengthening exercise that focuses on the leg muscles. Foot muscle strengthening aims to prevent injury to the feet, improve the

balance of physical activity in children and increase muscle endurance and power [4]. From the preliminary study that has been done, there are 13 children in grades 4,5, and 6 at SDN 5 Padangsambian who have flatfoot. This study aims to prove foot muscle strengthening to improve dynamic balance in children with flexible flatfoot.

2 Research Method

A. *Research Design*

This research is an experimental research design with pre and post-test control one group design, the sampling from the population is carried out randomly. Pre and post test control one group design compares the treatment in one group. The treatment group is foot muscle strengthening which consists of 13 children.

B. *Place and Time of Research*

This research was conducted at SDN 5 Padangsambian for 6 weeks with a frequency of 3 times a week.

C. *Sampling Technique*

The sampling technique used was random sampling. From the total population at SDN 5 Padangsambian, 120 children were selected according to the inclusion and exclusion criteria. The selected samples were randomized by lottery to get 13 samples according to the required number of samples. The division of groups was carried out at simple random from the selected subjects. Subjects received foot muscle strengthening intervention.

D. *Population and Sample*

The population in this study were elementary school students at SDN 5 Padangsambian. The sample in this study were elementary school students in grades 4,5,6 at SDN 5 Padangsambian who met the inclusion and exclusion criteria.

E. *Research Procedure*

The procedures of this research are: the preparation stage and the implementation stage. Preparation phase:

- a. Conducting consultations to ask for permission from the principal of SDN 5 Padangsambian
- b. The researcher makes a research permit and is signed by the Head of the Sports Physiology Study Program.
- c. The researcher gave an explanation to the sample.
- d. The population filled out the informed consent form.

Implementation stage:

- a. Perform history and physical examination on the subject.
- b. Determined the flexible flatfoot group which was included in the treatment group and the control group at random that met the inclusion criteria.

- c. Measure the arch using the wet foot print test before treatment.
- d. Conducted a pre-test by measuring the dynamic balance score using the balance beam walking test.

F. *Data Analysis*

- a. Descriptive statistics to describe physical characteristics including age, sex and body mass index (BMI)
- b. Data normality test with Saphiro Wilk Test, aims to determine the distribution of normal data or not in each treatment group. The limit of significance used is $= 0.05$. The result is $p > 0.05$ then the data is normally distributed.
- c. Test the homogeneity of the data with the Levene Test, which aims to determine the variation of the data. The limit of significance used is $= 0.05$. The result is $p > 0.05$ then the data is homogeneous.
- d. Test hypotheses I and II using Paired Samples t-test because the data is normally distributed. To test the difference in results before and after treatment in the intervention group. The result is $p < 0.05$ then H_0 is rejected or H_a is accepted there is a significant difference.

3 Research Result

- A. *Description of Research Subject Characteristics*
(See Table 1).
- B. *Normality and Homogeneity Test*
(See Table 2).
- C. *Different Test of Dynamic Balance Improvement Before and After Treatment*
(See Table 3).

Table 1. DESCRIPTION OF RESEARCH SUBJECT CHARACTERISTICS

Characteristic	Subject		
	Category	Intervention Group	%
Age	9 years old	5	38.5
	10 years old	3	23.1
	11 years old	4	30.8
	12 years old	1	7.7
Sex	Boy	8	61.5
	Girl	5	38.5
BMI	Underweight	8	61.5
	Normal	2	15.4
	Overweight	3	23.1

Table 2. NORMALITY AND HOMOGENEITY TEST

Data Group	Normality Test with Shapiro Wilk Test	Homogeneity Test with Levene's Test
	<i>Intervention Group</i> <i>p</i>	
Before Intervention	0.062	0.595
After Intervention	0.111	

Table 3. PAIRED SAMPLE TEST

Data Group	Paired Sample Test		
	<i>Before</i>	<i>After</i>	<i>p</i>
Intervention	1.46 ± 0.776	2.62 ± 0.870	0.000

4 Acknowledgment

The characteristics of the sample in this study were 8 male subjects (61.5%) and 5 female subjects (38.5%). Based on the data above, this is in accordance with Pfeiffer's 2006 statement in Lendra and Santoso's 2009 study explaining that boys tend to be more likely to experience flatfoot than girls, the prevalence of flatfoot in boys is 52% and 36% for girls. The prevalence of flexible flatfoot in the group of children aged 3–6 years was 44%, out of a total of 835 children (411 girls and 424 boys). Based from the age of the subject, the intervention group 9 years was 5 people (38.5%), age 10 years was 3 people (23.1%), age 11 years was 4 people (30.8%), age 12 years old as many as 1 person (7.7%) [7]. According to Nafarin's research in 2016, this age is the initial phase of increasing dynamic balance abilities in girls and boys. Optimization of dynamic balance requires physical activity exercises that can improve the components of dynamic balance [8].

Based from the BMI of subjects in the control group, underweight BMI is 8 subjects (61.5%), normal BMI were 2 (15.4%) and almost obese BMI was 3 (23.1%). Children who have ideal BMI values tend to have better balance scores than those with less ideal BMI and obesity. The balance function of the body involves the activity of muscle strength and accumulation of adipose tissue. In the research of Habut et al. In 2015, physical activity is a form of body movement that produces significant energy expenditure and is divided into light, medium and heavy groups produced by skeletal muscles. Each activity requires different energy depending on the intensity and work of the muscles [9].

The normality test was carried out with the Shapiro Wilk Test and the homogeneity test was carried out with the Lavene's Test. The variables tested were the increase in dynamic balance in children with flexible flatfoot before and after the intervention in each group and the difference in the increase in dynamic balance between before and after the intervention in the two groups of application. Based on the normality and homogeneity tests that have been carried out on all these variables, the results are $p > 0.05$. With

these results it can be concluded that the variables before and after treatment as well as the difference between the increase in dynamic balance in children with flexible flatfoot before and after treatment were normally distributed and homogeneous.

Fiolkowski et al. In a 2016 study, Eun Kyung Kim reported that sensory-motor exercises were applied to the body's proprioceptive feedback loop to activate the abductor pollicis and flexor hallucis brevis muscles, which are intrinsic muscles of the foot that are important for maintaining the medial longitudinal arch which serves to assist arch formation and maintain body balance. In addition, sensory-motor exercises provide proprioceptive sensory signals to the sensory cortex areas of the brain which will influence the motor areas to increase single asymmetrical muscles and attract new movements that are appropriate by increasing motor sensation and reducing postural disturbances by maintaining balance and body stability. Sensory stimulation training is beneficial for flatfoot patients to shape and support the arch by mobilizing extrinsic leg muscles such as the flexor digitorum longus muscle. However, foot muscle strengthening exercises are sensory-motor exercises that activate the intrinsic muscles of the foot and actively form the medial longitudinal arch [10].

Having the ability to adapt to a variety of ground surfaces makes the foot perform its rigid function as a lever to propel the body forward when walking and running with the help of several components, namely the medial longitudinal arch, plantar fascia, calcaneonavicular ligament, long and short plantar ligament. The medial longitudinal arch performs its function as a rigid structure when walking with an arch-spring mechanism and a windlass mechanism. When running both mechanisms, the arch will be compressed so that it moves like a spring because it extends during the early to mid-stance phase of the gait cycle. Then, the arch shortens at the end of the stance phase to help move the foot during the push-off phase, this is called the arch-spring. The transition of the arch from a flexible to a rigid structure is called the windlass mechanism of the plantar fascia, where the plantar fascia also stretches and shortens to allow the arch to move like a spring [13].

In the flat foot condition, there is a deficiency of the windlass mechanism because the plantar fascia cannot tighten when the metatarsophalangeal joint is extended. So it is less able to push the body forward when the foot leaves the footing in the push-off phase when walking [14].

The tibialis posterior muscle, which is the main supporter of the medial longitudinal arch, controls pronation of the foot by eccentric contraction and supination of the foot by concentric contraction. Excessive pronation of the flat foot occurs due to decreased shock absorption ability. The flat foot condition causes the plantar fascia to experience (overstretched), talonavicular joint hypermobility, increased pressure in the dorsal mid-foot area, and decreased movement of the posterior tibial tendon. The pain experienced by individuals with flat foot is caused by increased stress on the metatarsophalangeal joint, posterior tibial muscle and tendon, and plantar fascia [15].

The intrinsic muscles of the foot play an important role in maintaining stability or balance and providing support and assistance during activities of the foot [16].

In flat foot conditions, the intrinsic muscles tend to work harder, resulting in overused to stabilize the arch due to loss of passive support from the ligaments, resulting in leg fatigue and pain. Weakness of the intrinsic muscles of the foot such as the abductor

hallucis, flexor hallucis brevis, flexor digitorum brevis, and interosseus muscles which act as dynamic stabilizers of the medial longitudinal arch results in lower ability to absorb external pressure and postural instability. In addition, pressure in the plantar area is concentrated in the II and III metatarsals compared to the normal foot during dynamic activities such as walking. As a result, the distribution of plantar pressure changes which increases the risk of injury [17].

Although there is no definitive reason why individuals with flat foot have poor static and dynamic balance, it is possible that this could be due to structural and functional changes in the foot and the inability of the foot to absorb external forces [18]. The foot has sensory receptors in the form of a nervous system in the plantar fascia, ligaments, joint capsules, muscles and tendons in the plantar area that function as elements of the sensation of walking and balance. Sensory receptors in the intrinsic muscles of the foot can be more active if given stretching exercises so that they can provide information about changes in foot posture. Foot alignment that is not anatomical causes additional stress on the muscle spindles and tendons of the talocalcaneal joint which results in proprioceptive disturbances in the foot [12].

Foot muscle strengthening intervention can improve dynamic balance in children with flexible flatfoot. Based on the test results with the paired sample t-test in the intervention group, the mean before the intervention was 1.46 and after the intervention was 2.62 while the p value = 0.000 ($p < 0.05$) which means that there is a significant difference in the balance of foot muscle strengthening. This shows that foot muscle strengthening intervention can improve dynamic balance in children with flexible flatfoot. In Rahmawati's research, it was found that more than 50% of Raudhatul Athfal Taqiyaa Kartasura students aged 5–6 years had flatfoot feet with poor balance. Based on research conducted that gross motor exercise in flatfoot and hypotonic children get significant results. The main exercises for flatfoot children are strengthening and improving proprioception and postural balance. Repeated exercise and contraction will cause muscle fibers to enlarge so that muscle strength increases and balance increases [5].

Strengthening exercises lead to significant increases in static and dynamic. The increase in balance is due to the facilitation of the speed of the twitch motor unit so that it can improve muscle coordination in the process of decreasing disinhibition and stimulation of muscle spindles during strengthening exercises. In this condition, muscle contraction stimulates gamma efferent activity in muscle spindles. Increased sensitivity of muscle coils can improve the sense of joint position which has an important role in postural control. The results show that increasing strength can improve static and dynamic balance and postural control [6].

5 Conclusion

The present study showed that a foot muscle strengthening exercise for six weeks was sufficient to improve dynamic balance in children with flexible flatfoot. To enhance foot function more effectively, this foot muscle strengthening recommended for children with flexible flatfoot.

6 Suggestion

Based on the research that has been carried out, there are numbers of suggestion that researchers want to convey, they are as follows:

Foot muscle strengthening can be chosen to improve dynamic balance in children with flexible flatfoot.

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