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The Effect of Using 3d Printed Insole And Semi-Rigid Insole on Spatiotemporal Parameters in Students With Flexible Flat Foot Deformity

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Abstract

Background: The most common foot deformity in the community is the flexible flat foot where the MLA condition becomes flat. Flat foot deformity results in decreased spatiotemporal gait parameters and requires an orthosis like an insole. Usually, flat feet are given a semi-rigid insole, but there is an alternative to the modeling and fabrication process of the insole, called the 3D printing method.
Aims: To analyze the effect of 3D printed insole and semi-rigid insole on spatiotemporal gait parameters (walking speed, cadence, and step length).
Methods: Using a quantitative analysis with cross sectional design to observe the improvement on spatiotemporal gait parameters. Five flexible flatfeet participants were recruited and asked to walk about 10-meter with 3D printed insoles.
Results: There was an increase in walking speed after using 3D printed insoles on spatiotemporal parameters (speed, cadence, and stride length).
Conclusion: The use of a 3d printed insole can help improve walking speed in participants with flexible flat foot deformity.

Keywords: Flat foot, semi rigid insole, spatiotemporal gait parameter, walking speed, cadence, step length.

Article History

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Introduction

The human foot is a very complex structure and has an important role in movement. According to (Van Boerum & Sangeorzan, 2003) the human foot has 26 bones, 10 major extrinsic tendons and their respective muscles, various intrinsic musculotendinous units, and more than 30 joints. These musculoskeletal structures work together with the nervous system, fat pads, skin to provide sensation, movement, adaptive balance when standing and as a means of locomotion when walking. The main function of the foot is to enable movement and the ability to support body weight. The foot is also able to absorb pressure when walking. From a biomechanical perspective, the foot is also referred to as a "functional unit" with two important purposes: to support body weight (static) and provide propulsion (dynamic). When standing or moving, the whole body must function properly, especially the lower extremities, if the feet do not function normally, it results in the body and lower extremities not being optimal when supporting body weight.

Flat foot is a medical condition in which the medial longitudinal arch (MLA) along the surface of the foot is flat. (Chen et al., 2010). Flat foot cases occur in all parts of the world. In 2019, according to Kodithuwakku Arachchige et al., (2019), the prevalence of flat foot was reported to be around 25% in the general population. According to Franco in Chen et al. (2010) also said that flat foot deformity is usually treated with orthosis. The orthosis is designed to provide stability and shape the arch of the foot and has been shown to reduce flat foot symptoms in patients. (Chen et al., 2010).

Most insoles are custom-made, and the price is very expensive, making it difficult for people to get them. As technology develops, there is a fabrication method using 3D printing. This fabrication process is proven to be applicable in insole manufacturing and is considered faster than traditional techniques. The process facilitates the production of 3D objects at a more affordable price. (Kim & Joo, 2017).

Walking is a natural mode of movement for humans, allowing them to move independently and efficiently. According to Bonnefoy (2015), walking can be defined as a translational movement of the entire body caused by repetitive motion of body segments while maintaining balance. Within the walking cycle, various gait characteristics can be measured through spatiotemporal parameters such as walking speed, cadence, and stride length. The gait of individuals with flat feet differs from that of those with normal arches. According to Octavius et al. (2020), flat feet can lead to various issues including decreased walking speed, increased pressure on the foot's surface, and difficulty in performing daily activities.

There are distinctions between 3D printed insoles and conventional insoles concerning biomechanics in individuals with flat foot deformities. As asserted by Choo et al. (2020), 3D printed insole orthoses can effectively improve biomechanical and kinematic parameters, with their effectiveness not significantly different from that of conventional orthoses. Moreover, 3D printed insoles demonstrated superior results in walking parameters compared to conventional orthoses. Despite this, there remains a scarcity of studies examining walking biomechanics, especially regarding the spatiotemporal parameters of 3D printed insoles compared to conventional ones. Therefore, the aim of this study is to ascertain the impact of using 3D printed insoles with custom-made semi-rigid insoles on spatiotemporal parameters in individuals with flexible flat foot deformities.

Methods

This research is a quantitative study and includes a type of comparative observational analytic research where the researcher will observe directly to find out the comparison of the variables that will be the object of research. The research design used is a one-shot case study, where the researcher intervenes on the object of research. The subject of this study will get:

1. Treatment in the form of using 3D printed insoles and semi rigid insoles within a period of two weeks.
2. Participants performed the 10-meter walking test and walked on the footscan to obtain spatiotemporal parameter data.

The subjects chosen in this study were students of the Jakarta Polytechnic of Health Ministry I, Department of Orthotic Prosthetics, totaling 5 students. The samples taken have included criteria: healthy body condition and willingness to become research participants. Have flexible flat foot deformity. FPI (Foot Posture Index) score of +6 to +12. While the exclusion criteria include having deformities in the foot (hallux valgus, pes cavus, hammer, mallet, and or claw toe) and having neurological problems in the foot.

Results

Table 4.1 presents the demographic data of the participants, based on the table, the average age is 21 ± 0.71 years old with an age range from 20 to 22 years. The gender of the participants is female. The average body weight was 63.8 ± 11.82 kg with a body weight range of 53 to 83 kg. The average height was 158 ± 6.56 cm with a height range of 153 to 169 cm. The FPI score after observation has an average of 7.8 ± 0.84 with a score range of 7 to 9. Positive results on the FPI indicate pronated feet and flat MLA arches.

Table 1 Demographic Data of Participants

Characteristics	Mean ± SD	Minimum	Maximum
Age (year)	21 ± 0.71	20	22
Body weight (Kg)	63.8 ± 11.82	53	83
Body height (cm)	158 ± 6.56	153	169
FPI Score	7.8 ± 0.84	7	9

Table 1 presents the demographic data of the participants, based on the table, the average age is 21 ± 0.71 years old with an age range from 20 to 22 years. The gender of the participants is female. The average body weight was 63.8 ± 11.82 kg with a body weight range of 53 to 83 kg. The average height is 158 ± 6.56 cm with a height range of 153 to 169 cm. The FPI score after observation has an average of 7.8 ± 0.84 with a score range of 7 to 9. Positive results on the FPI indicate pronated feet and flat MLA arches.

Table 2 Frequency of Participants on Walking Speed Variable

Walking Speed	Frequency (n)	Percentage (%)
Slow	1	20
Medium	4	80
Total	5	100

Table 2 presents data on the frequency distribution of participants in the walking speed variable. The frequency of participants in the slow category was 1 person with a percentage of 20%. The frequency of participants in the medium category was 4 people with a percentage of 80%.

Table 3 Frequency of Participants on Cadence Variables

Cadence	Frequency (n)	Percentage (%)
Low	5	100
Total	5	100

Table 3 presents data on the frequency distribution of participants in the cadence variable. The frequency of participants in the low category was 5 people with a percentage of 100%.

Table 4 Frequency of Participants on Step Length Variable

Step Length	Frequency (n)	Percentage (%)
Short	1	20
Medium	4	80
Total	**5**	**100**

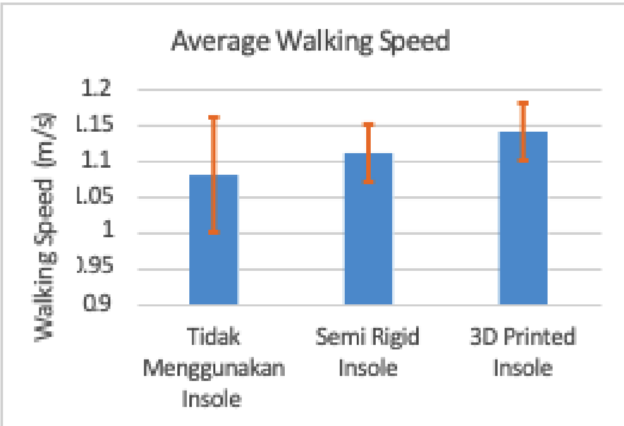
Table 4 presents data distribution of participants in on the frequency the step length variable. The frequency of participants in the short category was 1 person with a percentage of 20%. The frequency of participants in the medium category was 4 people with a percentage of 80%.

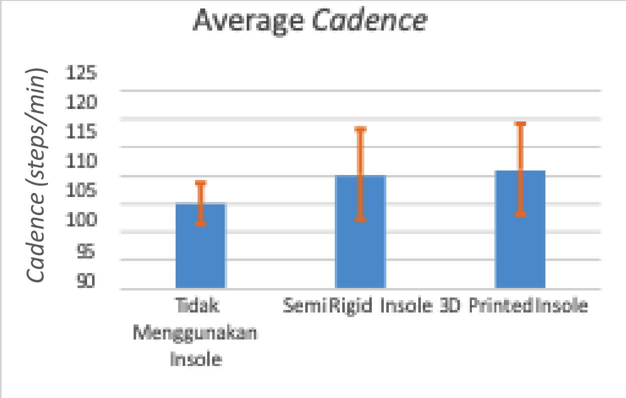
The following are data on walking speed, cadence, and stride length in the three shoe conditions with and without the use of an insole.

Table 5 Average Spatiotemporal Gait Parameters of the Three Treatments

Spatiotemporal Gait Parameters in Three Shoe Conditions	Mean ± SD	Minimum	Maximum
Walking Speed (m/s):			
Without Insole	1.08 ± 0.08	1.00	1.21
Using Semi Rigid Insole	1.11 ± 0.03	1.07	1.16
Using 3D Insole	1.14 ± 0.04	1.09	1.20
Cadence (steps/min):			
Without Insole	105 ± 3.56	101	109
Using Semi Rigid Insole	110 ± 7.86	100	117
Using 3D Insole	111 ± 7.85	103	122
Step Length (cm):			
Without Insole	50.66 ± 8.84	35.40	58.25
Using Semi Rigid Insole	52.19 ± 7.82	42.65	59.40
Using 3D Insole	56.46 ± 1.38	55.25	58.30

Graph 1 Bar Chart Average Spatiotemporal Gait Parameter for Three Treatments





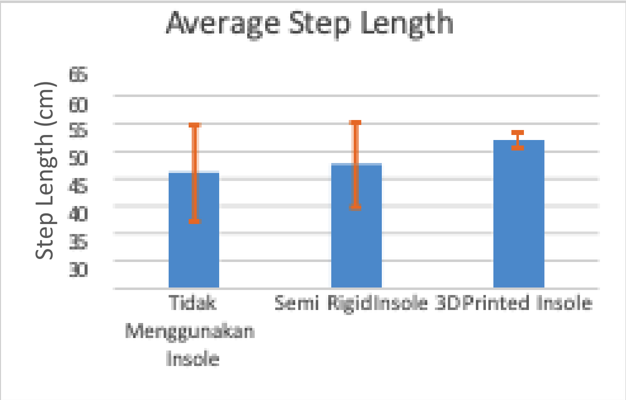


Table 3 presents the mean, minimum and maximum values of the spatiotemporal gait parameter variables (speed, cadence, and stride length) in the three shoe conditions. The average walking speed without using an insole was 1.08 ± 0.08 m/s with a minimum value of 1.00 m/s and a maximum value of 1.21 m/s. The average walking speed using a semi rigid insole was 1.11 ± 0.03 with a minimum value of 1.07 m/s and a maximum value of 1.16 m/s. The average walking speed using 3D printed insoles is 1.14 ± 0.04 m/s with a minimum value of 1.09 m/s and a maximum value of 1.20 m/s.

The average cadence without using insoles is 104.8 ± 3.56 steps/min with a minimum value of 101 steps/min and a maximum value of 109 steps/min. The average cadence using a semi rigid insole was 109.6 ± 7.86 steps/min with a minimum value of 100 steps/min and a maximum value of 117 steps/min. The average cadence using 3D printed insoles is 111.2 ± 7.85 steps/min with a minimum value of 103 steps/min and a maximum value of 122 steps/min.

The average stride length without using insoles is50.66 ± 8.84 cm with a minimum value of 35.40 cm and a maximum value of 58.25 cm. The average stride length using a semi rigid insole was 52.19 ± 7.82 cm with a minimum value of 42.65 cm and a maximum value of 59.4 cm. The average stride length using 3D printed insoles is 56.46 ± 1.38 cm with a minimum value of 55.25 cm and a maximum value of 58.3 cm. Graph 1 presents the spatiotemporal average data of the parameters (walking speed, cadence, and stride length) in the form of a bar chart and the red line shows the standard deviation.

Discussion

Based on the theory of Barati et al., (2019) biomechanically, the insole optimizes the energy transferred during the push-off phase of the walking cycle. This is due to the windlass effect obtained when the sub talar joint is in supination. In flat foot deformity, the foot posture is pronounced with a flat MLA so there is almost no supination movement during the terminal stance phase. The insole helps correct the foot deformity and supports the MLA so that in the push-off phase there is a windlass mechanism. This increases the mobility of the foot when walking, thereby increasing walking speed.

In general, 3D printed insoles have a positive impact on walking biomechanics when compared to conventional orthosis using semi rigid insoles. Insole has a great role in conservative treatment of flexible flat foot deformity. 3D printed insoles can help improve the shape of MLA. Based on the insole fabrication process using 3D printing, the results show that the process has many advantages. Hsu et al, (2022) said, insoles made with 3D printing methods can reduce processing time and material costs when compared to conventional insoles. The researcher agrees with this statement because the processing time is proven to be faster in making 3D printed insoles. In terms of cost, conventional insoles cost more than 3D printed insoles because it must go through a long procedure such as casting, rectification, fabrication, thermo-forming and finishing. Materials and machines used are more and take longer time in the conventional insole manufacturing process. Meanwhile, the fabrication process using 3D printing can be three times faster and more efficient than using conventional fabrication. In terms of material, the main material in 3D printed insoles is Polylactic Acid (PLA). The characteristics of PLA, which is proven to be strong like plastic, is a mechanical advantage, making it capable of accepting large pressure on the body. Therefore, the effect of 3D printed insoles in walking biomechanics is superior to conventional insoles.

The results of bivariate data on cadence and stride length variables when using semi rigid insoles and 3D printed insoles were not significant, however small improvement can be seen for stride length with 4.27 cm and 1 steps/min for steps.

Conclusion and Recommendation

The highest spatiotemporal parameter results are dominated by the condition using 3D printed insoles. As stated by Choo et al. (2020) from studies that have been done before, 3D printed orthotic insoles have superior or similar results in spatiotemporal gait parameters compared to conventional orthosis. This statement also agrees with Y.-K. Kim & Joo, (2018) who said that the use of 3D printed insoles has an influence on increasing the value of spatiotemporal parameters, especially in walking speed. Both theories are in line with the results of this study, that the 3D printed insole is proven to have increased spatiotemporal parameters. In general, 3D printed insoles have a positive impact on walking biomechanics when compared to conventional orthosis using semi rigid insoles.

Based on the results of the analysis and discussion, the conclusions that can be drawn from research on the effect of using 3d printed insole and semi rigid insole on spatiotemporal walking parameters in students with flexible flatfoot deformity are as follows:

1. There was an improvement in spatiotemporal parameters between before and after insole use for participants with flexible flat feet.

2. There is a significant improvement in the use of 3D printed insoles with semi rigid insoles on the spatiotemporal value of walking speed parameters. 3D printed insoles are superior in walking speed, cadence, and stride length than semi rigid insoles.

3D printed insoles can be used as an alternative intervention for people who have flexible flat foot deformity and can improve the value of spatiotemporal parameters.

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