# The characteristic of arch height, and influence on dynamic balance by intervention of exercise in flatfoot

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**[Introduction]** The foot provides the base of support in weight bearing when standing, walking, running and doing lot of exercise. The most fundamental factor is the medial longitudinal arch (MLA), as it plays a vital role in the transfer of forces through the foot. The collapse of MLA demonstrates a foot abnormality known as “flatfoot” or “pes planus”. There are two types of flatfoot: rigid flat foot and flexible flat foot. Flexible flatfoot is caused by many factors and could be possible to revert to near normal foot. Therefore, the main investigation in the present study is the characteristic of flexible flatfoot. Since the prognosis of pediatric flatfoot and the precise time of intervention are important, there are more studies about children than adults. However, the proportion of people with flatfoot increases with increasing BMI, especially in women, and since the fatigue and flatfoot are significantly related, it is considered that the foot structure of adults is also important.

Flatfoot could have an influence on symptoms, structural or functional deformation. Because of the descending MLA in flatfoot, the ability to absorb impacts will decrease and the sense of balance will be lost so that stability decreases during walking or running leading to walking difficulties and endurance decreases. Posture control strategy of dynamic stability undergoes influence which is complicated and is related with flexibility, strength, balance and proprioception. And the studies about mechanism of dynamic stability between flatfoot and neutral foot are insufficient.

To correct the MLA, there is non-invasive treatment to increase the arch height. The “short-foot” exercise (SFE) can recruit the intrinsic foot musculature independently of extrinsic foot musculature and improve flatfoot conditions through changes in the height of the MLA. However, little is known about the influence of mechanism of dynamic stability after intervention of exercise in flatfoot.

**[Objective]** (1) STUDY 1: To investigate the relationships between age, BMI, genders, dominant side and exercise frequency to the arch height index. (2) STUDY 2: To investigate the influence of dynamic by SFE in flatfoot and the maintainability of the influence.

**[Method]** STUDY 1: A total of 514 healthy participants of both genders, aged 10 to 80, were recruited. The items of measurement are (1) Foot shape by three-dimensional foot type instrument (2) Questionnaire. STUDY 2: Twenty-nine healthy students aged between 20 and 35 were enrolled in this study and were assigned to Control group (15 subjects) and Flatfoot group (14 subjects) by FPI-6. The items of measurement are (1) Foot shape by three-dimensional foot type instrument (2) Questionnaire (3) The trail of COP was measured by F-Scan when doing Y balance test. Flatfoot group performed 4 weeks of the Short-Foot Exercise (SFE) and measured the maintainability after three weeks.

**[Results]** STUDY 1: Curvilinear regression analysis showed that there was significant relationship between arch height index and age in the right side ($R^2 = 0.072$, $P < 0.05$) and in the left side ($R^2 = 0.048$, $P < 0.05$), and there was significant relationship between arch height index

and BMI in the both side (Right: $R^2 = 0.027$, $P < 0.05$, Left: $R^2 = 0.019$, $P < 0.05$). An independent t-test showed that there were significant differences in foot length, arch height index and foot width between dominant sides. However, the dominant side is significantly bigger than the non-dominant side only in foot width.

STUDY 2: An independent t-test showed that there were significant differences in the trail of COP in the ML direction between Control group and Flatfoot group in three directions. Paired t-tests showed significant increases ($p<0.05$) to arch height index between pre-testing and post-testing in both sides but no significance to the trail of COP in the ML direction between pre-testing and post-testing. ANOVA showed that there were significant differences in arch height index between pre-testing to post-testing, follow-up 1 and follow-up 2, and there were significant differences in the trail of COP in the ML direction between pre-testing to follow-up 1 and follow-up 2 but no significant differences between pre-testing to post-testing in three directions.

**[Discussion]** STUDY 1: The present results show that the relationship between arch height index and age is increasing before age of 40 and starts to decline from age of 40. One of the reasons about flatfoot is due to the weakening of the muscles and ligaments that support the arch height, and the reduction of muscle strength with age may also affect the arch height index. Another important finding in the present study is excess weight (BMI > 25) was associated with lower arch height, and It could be possible that the reduction of arch height index is due to the excess weight collapsing the bony structure of the MLA.

There were significant differences in foot length, foot width and arch height index, but only in foot width, the dominant side is significantly bigger than the non-dominant side. It could be possible that the dominant foot is often used to be the axis side and have more loading than another side.

STUDY 2: The trail of COP in the ML direction of flatfoot group was significantly smaller than that of control group. The reason of the narrower COP in the ML direction which is considered is that the participant who has flatfoot did not use the intrinsic foot muscle very often to control the posture strategy, so it could not widen the COP in the ML direction. After four weeks of exercise, the significant increases to arch height index between pre-testing and post-testing in both sides of flatfoot group were found. This indicates that the flexible flatfoot can form the arch close to that of normal feet through exercise through SFE.

Even the exercise was finished, the effect of MLA could maintain at least three weeks. It could be possible that when SFE was implemented, the foot intrinsic muscle was activated and learned how to use. In the trail of COP in the ML direction, there were significant differences between pre-testing to follow-up 1 and follow-up 2 but no significant differences between pre-testing and post-testing in three directions. It is considered that although YBT was not difficult enough to reveal immediately changes in the trail of COP in the ML direction, after the foot intrinsic muscle was activated and learned how to use, it can be trained in daily life to widen the trail of COP in the ML direction to close to that of control group.

**[Conclusion]** STUDY 1: (1) The relationship between arch height index and age is increasing before age of 40, and starts to decline from age of 40, and the relationship between arch height index and BMI is declined in excess weight. (2) The arch height index in male was higher than in females. (3) Only in foot width, the dominant side is significantly bigger than the non-dominant side. STUDY 2: (1) The trail of COP in the ML direction of flatfoot was narrower than that of neutral foot. (2) The intervention of SFE for four weeks could effectively improve the arch height and maintain the height for at least three weeks.