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Weak TGS Correlates with Hallux Valgus in 10–12 Year Old Girls: A Cross-Sectional Study

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Abstract

Objective: Hallux valgus is one of the most common foot deformities. It is considered that hallux valgus is associated with foot arch height, footwear, sex and so on. Toe grip strength (TGS) is important for developing foot posture because it attributes to foot arch height. The relationship between hallux valgus and TGS in children is unknown, although childhood is a key period for developing foot posture. The objective of this study is to investigate the relationship between hallux valgus angle (HVA) and TGS in children.

Methods: A total of 671 (1342 feet) 10-12 year old children (boys, n = 317, age = 10.3 ± 0.7; girls, n = 354, age = 10.2 ± 0.7; means ± standard deviation [SD]) participated in this study. HVA, the angle between the first metatarsal axis and the proximal phalangeal axis, was measured using a goniometer. TGS was measured using a toe grip dynamometer. Differences in the data between boys and girls were analyzed using the Mann-Whitney U test. According to sex, single and multiple linear regression analyses with generalized estimating equations were performed for the relationship between HVA and TGS. The level of statistical significance was set at $p < 0.05$.

Results: The TGS and HVA of participants' feet were 13.3 ± 4.0 kg (boys, 13.4 ± 3.9 kg; girls, 13.1 ± 4.1 kg) and 7.9 ± 5.0° (boys, 6.7 ± 4.5°; girls, 9.2 ± 5.1°, $p < 0.001$). The multiple linear regression analysis in girls indicated a correlation between TGS and HVA ($\beta = -0.098$, $p = 0.045$), whereas in boys, there was no correlation.

Conclusions: HVA is greater in girls than in boys, and in girls, weak TGS correlates with hallux valgus. Weak TGS may attribute to hallux valgus in potential stage or early stage. Strengthening TGS may be as promising tool for preventing the onset of hallux valgus and for developing good foot posture.

Keywords: Toe grip strength; Hallux valgus; Girls; Children; Arch height; Foot deformity; Multiple linear regression

Introduction

For human beings, the feet are the only parts of the body connected to the ground and have important roles in standing and walking. Many people suffer from foot deformities, such as hallux valgus, flatfoot, and claw toe [1,2]. In particular, hallux valgus is one of the most common foot deformities and has a prevalence of 28.4% in adults [3].

Hallux valgus is a progressive foot deformity and is characterized by a lateral deviation of the first metatarsal. Hallux valgus often causes foot pain [4], increases the risk of falling in older people [5], and also decreases health-related quality of life [4]. Previous studies have reported several potential factors that contribute to hallux valgus, which include age [6], sex [7,8], genetics [9], length of first metatarsal [10], and footwear [11]. Despite the conducting of many studies, outside of surgery, effective methods of prevention and treatment have not yet been established.

Childhood is the key period for developing foot posture such as the medial longitudinal arch [12,13], low height of which contributes to hallux valgus [14]. There are fewer children with hallux valgus than adults, but due to slow progressive symptoms, they may be in a potential or early stage of hallux valgus. Especially, children at the age from 10-12 are in a period of development of secondary sex characteristics [15], when joint laxity is increased [16].

The differences of physical development between boys and girls may contribute to a greater incidence of hallux valgus in women than men. Therefore, the age from 10-12 may be an important period for onset of hallux valgus. In addition, because the occurrence of hallux valgus angle (HVA) in junior high school students increased between 1993 and 2003 [17], it may be necessary to examine the importance of hallux valgus in children. Because there are fewer studies about hallux valgus in children, the cause of hallux valgus in children remains unclear.

Recently, toe grip strength (TGS) and its crucial role in the push-off phase during walking have begun to draw a lot of attention in the podiatric community. An earlier study reported that an increase of TGS improves physical performance in many areas. It increases walking speed [18] and decreases falling risk [5] in daily life while it also increases sprint speed and jumping power [19] in sports.

TGS is also important because it contributes to medial longitudinal and transverse arch height [20], and low foot arches contribute to hallux valgus [14,20]. Also TGS is associated with the intrinsic foot muscle, which is important for developing foot posture and is associated with toe deformities, such as claw toe and hammer toe, when it is not functioning properly [21]. Therefore, for developing good foot posture, TGS is an essential element, especially in children who are in a key period for developing foot posture.

However, the relationship between hallux valgus and TGS in children is unknown. Understanding the relationship between hallux valgus and TGS in the potential or early stages of hallux valgus is helpful for prevention and treatment of hallux valgus. For this reason, in this study, we investigated the relationship between HVA and TGS in children.

Methods

Participants

In total, 671 (1342 feet) 10-12 year-old children (boys, n = 317, age = 10.3 ± 0.7; girls, n = 354, age = 10.2 ± 0.7; mean ± SD) participated in this study and were recruited from each elementary school in Tawaramoto, a town in Nara prefecture in Japan (Table 1). We obtained signed consent forms from the principals of these elementary schools for inclusion of their students in the study.

None of the participants reported having a history of foot surgery or congenital disorders. The methods and procedures used in this study were in accordance with the current local guidelines and the Declaration of Helsinki, and were approved by the Ethical Committee for Human Experiments (R0109) of Kyoto University.

Experimental protocol

The most common diagnostic method for hallux valgus is the evaluation of HVA, the angle between the first metatarsal axis and the proximal phalangeal axis. HVA was measured using a goniometer. The protocol of measuring HVA as described by Kilmartin [22].

Briefly, the participants were in standing position with bare feet. One arm of the finger goniometer was brought against the mid-line of the medial surface of the hallux, and the other arm was brought against the mid-line of the medial surface of the first metatarsal (Figure 1). Test-retest reliability of two measurements of HVA with a 1-week interval was excellent (intra-class correlation coefficient = 0.965) in a sample of 28 feet.

TGS was measured using a toe grip dynamometer (T.K.K3362; Takei Scientific Instruments, Niigata, Japan). We measured TGS in accordance with a previous study [23]. The participants were sitting upright in chairs without leaning on the backrest throughout the toe grip strength measurement. Both of their hips and knees were bent at about 90 degree angles and their ankles were held in a neutral position with a strap.

The first proximal phalanx was positioned at the grip bar, and the heel was stabilized with the heel stopper adjusted optimally. The students gripped the grip bar with their toes using maximal effort for approximately 3 seconds (Figure 1). Measurements were conducted alternately with both right and left feet and repeated twice. The maximum value of 2 trials in each foot was used for further analysis.

Figure 1: Measurement of hallux valgus angle (HVA) and toe grip strength (TGS). (a), HVA, the angle between the mid-line of the medial surface of the hallux and the mid-line of the medial surface of the first metatarsal, was measured using a goniometer. (b), TGS using a toe grip dynamometer. The first proximal phalanx was positioned at the grip bar, and the heel was stabilized with the heel stopper adjusted optimally.

Statistical Analysis

The characteristics of the participants and their feet were summarized by using means and standard deviation (SD) for continuous variables. The foot characteristics data is comprised of the data from both feet of a participant. Differences in the data between boys and girls were analyzed using the Mann-Whitney U test.

Simple and multiple linear regression analyses with generalized estimating equations, to account for potentially correlated outcomes for feet from same individual, were performed to determine the association between TGS and HVA, according to sex. In both simple and multiple linear regression analyses, HVA was considered as the dependent variable, and TGS was the independent variable.

The multiple linear regression analysis was conducted to adjust moderator valuables (age, height, and weight). The level of statistical significance was set at $p < 0.05$, and statistical analyses were conducted using the SPSS version 20.0 software package (IBM Corp, Armonk, New York).

Results

Table 1 shows the participants and feet characteristics. The height and weight of participants were 141.3 ± 7.9 cm (boys, 140.7 ± 0.7 cm; girls, 142.0 ± 8.3 cm, $p = 0.024$) and 35.2 ± 7.9 kg (boys, 35.1 ± 7.7 kg; girls, 35.3 ± 8.3 kg). The TGS and HVA of participants' feet were 13.3 ± 4.0 kg (boys, 13.4 ± 3.9 kg; girls, 13.1 ± 4.1 kg) and 7.9 ± 5.0° (boys, 6.7 ± 4.5°; girls, 9.2 ± 5.1°, $p < 0.001$).

Table 2 shows the results of simple and multiple linear regression analyses with generalized estimating equations, according to sex. The simple linear regression analysis in both boys and girls indicated no correlation between TGS and HVA. By contrast, the multiple linear regression analysis in girls indicated a negative correlation between TGS and HVA ($\beta = -0.098$, $p = 0.045$), whereas in boys, there was no correlation.

	All	Boys	Girls	p value
Characteristics of Participants				
n	671	354	317	
age (year)	10.3 ± 0.7	10.2 ± 0.7	10.3 ± 0.7	0.586
height (cm)	141.3 ± 7.9	140.7 ± 7.5	142.0 ± 8.3	0.024*
weight (kg)	35.2 ± 7.9	35.1 ± 7.7	35.3 ± 8.3	0.902
Characteristics of Feet				
n	1342	708	634	
TGS (kg)	13.3 ± 4.0	13.4 ± 3.9	13.1 ± 4.1	0.062
HVA ()	7.9 ± 5.0	6.7 ± 4.5	9.2 ± 5.1	< 0.001**
*p < 0.05, **p < 0.01				
HVA: Hallux Valgus Angle; TGS: Toe Grip Strength				

Table 1: Comparison of the participants and foot characteristics between boys and girls by Mann-Whitney U test.

	Model 1		Model 2	
	β (95% CI)	p value	β (95% CI)	p value
boys	0.035 (-0.066 to 0.099)	50.10%	-0.063 (-0.173 to 0.047)	0.262
girls	-0.021 (-0.103 to 0.103)	0.652	-0.098 (-0.194 to -0.002)	0.045*
*p < 0.05				
model 1: simple linear regression analysis of TGS and HVA; model 2: multiple linear regression analysis of TGS and HVA adjusted for age, height and weight				
HVA: Hallux Valgus Angle; TGS: Toe Grip Strength				

Table 2: The association between TGS and HVA based on simple linear regression model and multiple linear regression model adjusted for age, height and weight.

Discussion

This study showed that HVA was greater in girls than in boys, and in girls, weak TGS correlates with hallux valgus in 10-12 year old children. The relationship between TGS and HVA observed in this study corresponds to the findings in a previous study, although those participants were older people [5].

Current study indicated, in 10-12 years old children, HVA was greater in girls than boys, and similar results in adults reported in previous studies [7,8]. Female research participants with hallux valgus had a less stable joint due to the rounder and smaller surface of the metatarsal head articulation [24].

In general, in women, ligamentous laxity is more common [25,26], and the first metatarsal is more likely to be adducted [27]. These characteristics in women may lead to the development of hallux valgus. On the contrary, there were a correlation between HVA and TGS because the girls might be in development of secondary sex characteristics. In boys, the period of development of secondary sex characteristics are later than girls [15]. Therefore, there may be a correlation between HVA and TGS in older boys as well as girls.

Our findings indicate that weak TGS may cause an increase of HVA. The major determinants of TGS are medial parts of plantar intrinsic muscles [28]; these muscles are one of the components of medial longitudinal arch. Additionally, Hashimoto et al. [19] revealed that toe flexor strength training heightens medial longitudinal and transverse arches. These arches are collapsed in foot with hallux valgus [14,20]. Particularly in children, TGS is more important for arch development because the arches develop in the first decade of life [12,13]. This is the reason that there is no correlation between HVA and TGS in Japanese adults aged 20 to 79 years in the Uritani et al. [23] study. Conversely, this study showed the correlation between HVA and TGS using the same method as the Uritani et al. [23] study.

In general, low foot arches caused by weak TGS possibly increases HVA in children. Hence, strengthening TGS may be helpful in preventing the onset of hallux valgus or decreasing HVA in children, who are developing foot posture.

On the contrary, the alignment change and foot pain induced by increased HVA may cause the weakening of TGS. The extensor hallucis longus tendon shifts more toward the fibula with severe hallux valgus [29]. Additionally, in patients with hallux valgus, the first metatarsal head is more pronated [30], and this may have first distal phalange, in which the extensor hallucis longus tendon attaches also and is, pronated. These result in the extensor hallucis longus tendon being stretched and becoming taut, keeping the big toe extended. Hence, the flexor ability of the big toe may decrease. As a result, the larger HVA is, the less the ability of flexing the big toe. Conversely, a previous study reported that foot pain induced by hallux valgus decreases hallux flexor strength. An alignment change and foot pain often accompany severe hallux valgus, although there were few participants with severe hallux valgus in this study. However, the possibility that increased HVA may cause the weakening of TGS cannot be denied.

There was a significant correlation between TGS and HVA by multiple linear regression analysis adjusting moderator valuables (age, height, and weight) but no significance in the simple regression analysis. The reason for the difference in results is that age, height, and weight are potential and impactful factors in HVA and TGS. In childhood, increase of age, height, and weight means physical growth. Due to progressive disorder of hallux valgus, HVA may increase with physical growth in children. TGS also increases with physical growth because muscle strength correlates with physical growth [31]. HVA and TGS also have a positive effect on physical growth, despite the negative relationship between HVA and TGS in children. Therefore, there was no significant relationship between HVA and TGS by simple regression analysis.

There was significant correlation between TGS and HVA in girls but no significance in boys. Ligamentous laxity, which is more common in girls, contributes to foot posture such as flatfoot [26], which is associated with hallux valgus [14]. TGS correlates with medial longitudinal arch height, which is decreased in flatfoot. Therefore, in girls, TGS may be more important for maintaining the normal foot posture due to their proneness to ligamentous laxity.

There are some limitations to our study. First, the assessment of HVA is conducted using x-ray images in most studies but using a goniometer in this study. However, there is a correlation (r = 0.63) between HVA measured with a goniometer and x-ray images [22]. Hence, HVA measured using a goniometer is permissible. Second,

factors increasing HVA, such as genetics, length of first metatarsal and footwear are not taken into consideration. There's a possibility that hallux valgus is a hereditary disease or gene associated disease. Hallux valgus are found in the patients with disease seem to be autosomal recessive disorders [32] which may be caused by mutants within a certain imprinted gene. Therefore, for finding out what cause hallux valgus, it is worth to investigate genetic factor such as genomic imprinting [33,34]. We did not consider factors such as longitudinal and transverse arch height, alignment change, and foot pain, which may influence the relationship between HVA and TGS. Finally, due to the cross-sectional design, the causal association between HVA and TGS-whether weak TGS contributes to the increase of HVA or whether increased HVA causes the weakening of TGS-is unknown. Further research is required to reveal the relationship between HVA and TGS. However, our findings suggest that strengthening TGS may be helpful in preventing the onset of hallux valgus during childhood.

Conclusion

This study shows that weak TGS correlates with hallux valgus in 10-12 year–old girls. Weak TGS may contribute to hallux valgus in the potential or early stages. Therefore, strengthening TGS is meaningful for preventing the onset of hallux valgus and developing good foot posture.

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Competing Interests

The authors declare that they have no competing interests.

References

1. Janchai S, Chaiwanichsiri D, Silpipat N, Tiamprasitt J (2008) Ageing feet and plantar arch characteristics of the Thai elderly. Asian Biomed 2: 297-303.
2. Espinoza-Navarro O, Urquieta MO, Navarrete PP, Flores NR (2013) Prevalence of foot anomalies in school children between 6 and 12 years old of elementary education from Arica-Chile. Int J Morphol 31: 162-168.
3. Roddy E, Zhang W, Doherty M (2008) Prevalence and associations of hallux valgus in a primary care population. Arthritis Rheum 59: 857-862.
4. Menz HB, Roddy E, Thomas E, Croft PR (2011) Impact of hallux valgus severity on general and foot-specific health-related quality of life. Arthritis Care Res (Hoboken) 63: 396-404.
5. Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR (2009) ISB Clinical Biomechanics Award 2009: toe weakness and deformity increase the risk of falls in older people. Clin Biomech (Bristol, Avon) 24: 787-791.
6. Turan I (1990) Correlation between hallux valgus angle and age. J Foot Surg 29: 327-329.
7. Barnicot NA, Hardy RH (1955) The position of the hallux in West Africans. J Anat 89: 355-361.
8. Maclennan R (1966) Prevalence of hallux valgus in a neolithic New Guinea population. Lancet 1: 1398-1400.
9. Coughlin MJ (1995) Roger A. Mann Award. Juvenile hallux valgus: etiology and treatment. Foot Ankle Int 16: 682-697.
10. Munuera PV, Polo J, Rebollo J (2008) Length of the first metatarsal and hallux in hallux valgus in the initial stage. Int Orthop 32: 489-495.
11. Nguyen U, Hillstrom HJ, Li W, Dufour AB, Kiel DP, et al. (2010) Factors associated with hallux valgus in a population-based study of older women and men: the Mobilize Boston Study. Osteoarthritis Cartilage 18: 41-46.
12. Cappello T, Song KM (1998) Determining treatment of flatfeet in children. Curr Opin Pediatr 10: 77-81.
13. Volpon JB (1994) Footprint analysis during the growth period. J Pediatr Orthop 14: 83-85.
14. Komeda T, Tanaka Y, Takakura Y, Fujii T, Samoto N, et al. (2001) Evaluation of the longitudinal arch of the foot with hallux valgus using a newly developed two-dimensional coordinate system. J Orthop Sci 6: 110-118.
15. Frazier JA, AlaghbandRad J, Jacobsen L, Lenane MC, Hamburger S, et al. (1997) Pubertal development and onset of psychosis in childhood onset schizophrenia. Psychiatry Res 70: 1-7.
16. Flynn JM, Mackenzie W, Kolstad K, Sandifer E, Jawad AF, et al. (2000) Objective evaluation of knee laxity in children. J Pediatr Orthop 20: 259-263.
17. Sato M, Umemura M, Masaki S (2003) Study of valgus angles of great toe in the young adults -comparison to the former study done 10 years ago. Jap Soc Med Study Footwear 17: 51-53.
18. Misu S, Doi T, Asai T, Sawa R, Tsutsumimoto K, et al. (2014) Association between toe flexor strength and spatiotemporal gait parameters in community-dwelling older people. J Neuroeng Rehabil 11: 143.
19. Hashimoto T, Sakuraba K (2014) Strength training for the intrinsic flexor muscles of the foot: effects on muscle strength, the foot arch, and dynamic parameters before and after the training. J Phys Ther Sci 26: 373-376.
20. Suzuki J, Tanaka Y, Takaoka T, Kadono K, Takakura Y (2004) Axial radiographic evaluation in hallux valgus: evaluation of the transverse arch in the forefoot. J Orthop Sci 9: 446-451.
21. Myerson MS, Shereff MJ (1989) The pathological anatomy of claw and hammer toes. J Bone Joint Surg Am 71: 45-49.
22. Kilmartin TE (1994) The orthotic treatment of juvenile hallux valgus [dissertation]. Nottingham University 108-110.
23. Uritani D, Fukumoto T, Matsumoto D, Shima M (2014) Reference values for toe grip strength among Japanese adults aged 20 to 79 years: a cross-sectional study. J Foot Ankle Res 7: 28.
24. Ferrari J, Malone-Lee J (2002) The shape of the metatarsal head as a cause of hallux abductovalgus. Foot Ankle Int 23: 236-242.
25. Wilkerson RD, Mason MA (2000) Differences in men's and women's mean ankle ligamentous laxity. Iowa Orthop J 20: 46-48.
26. Falotico GG, Uyeda MTdL, Romão RAL, Freitas ASPd, Blumetti FC, et al. (2010) Ligament laxity and flatfoot in normal children. Rev Bras Ortop 45: 25-30.
27. Frey C, Thompson F, Smith J, Sanders M, Horstman H (1993) American orthopaedic foot and ankle society women's shoe survey. Foot Ankle 14: 78-81.
28. Kurihara T, Yamauchi J, Otsuka M, Tottori N, Hashimoto T, et al. (2014) Maximum toe flexor muscle strength and quantitative analysis of human plantar intrinsic and extrinsic muscles by a magnetic resonance imaging technique. J Foot Ankle Res 7: 6.
29. Kelikian H (1982) The hallux: disorders of the foot. W.B. Saunders Company, Philadelphia 539-621.
30. Mortier JP, Bernard JL, Maestro M (2012) Axial rotation of the first metatarsal head in a normal population and hallux valgus patients. Orthop Traumatol Surg Res 98: 677-683.
31. Düppe H, Cooper C, Gärdsell P, Johnell O (1997) The relationship between childhood growth, bone mass, and muscle strength in male and female adolescents. Calcif Tissue Int 60: 405-409.
32. Boudhina T, Yedes A, Khiari S, Ghram N, Ben Becher S, et al. (1990) Familial syndrome combining short stature, microcephaly, mental deficiency, seizures, hearing loss, and skin lesions. A new syndrome. Ann Pediatr (Paris) 37: 399-403.
33. Bird A (2002) DNA methylation patterns and epigenetic memory. Genes Dev 16: 6-21.

34. Zhang T, Termanis A, Ozkan B, Bao XX, Culley J, et al. (2016) G9a/GLP Complex Maintains Imprinted DNA Methylation in Embryonic Stem Cells. Cell Rep 15: 77-85.