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Correlation Between Hallux Flexor Strength and Dynamic Balance in Chronic Ankle Sprain Individuals - A Pilot Study

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ABSTRACT

Background: Lateral ankle sprain stands out as a prevalent injury in both competitive sports and recreational pursuits. Athletes reported residual ankle pain, instability, and weakness. People who have Chronic ankle instability frequently have mechanical deficits, sensorimotor deficits, or a combination of both. Flexor hallucis weakness and decreased toe-flexion strength have been observed in these patients, in order to maintain balance, the extrinsic toe flexors at the ankle joint and all of the toe flexors against the supporting surface through the pads of the planted foot's toes must provide the maximum amount of plantar flexor force. Therefore, the aim of this study is to correlate between hallux flexor strength and dynamic balance in chronic ankle sprains individuals
Methods: The study included 20 individuals with Chronic ankle sprain. Each participant's great toe flexor strength was measured by pinch gauge dynamometer and dynamic balance was assessed using star excursion balance test. Data was analysed using SPSS version 20.0 and p value less than 0.05 was considered statistically significant.
Findings: The correlation analysis between the Star Excursion Balance Test scores and hallux flexor strength (lbs) yielded a correlation coefficient (r value) of -0.122 and a corresponding p-value of 0.562. p value >0.05 shows correlation is not statistically significant. Therefore, there is insufficient evidence to conclude a significant correlation between Star Excursion Balance Test scores and hallux flexor strength based on the provided data.
Conclusion: According to the study's findings, the hallux flexor strength does not influence dynamic balance in chronic ankle sprain individuals

Keywords: Chronic ankle sprain, Chronic ankle instability, Hallux flexor strength, Flexor hallucis longus, Dynamic balance, Star excursion balance test

INTRODUCTION

Lateral ankle sprain stands out as a prevalent injury in both competitive sports and recreational pursuits. Within athletic domains, ankle injuries make up a significant portion, ranging from 10% to 30% of all injuries, and even higher proportions, between 40% to 56%, in specific sports. [1]

Ankle joint stability relies on three primary factors: 1) The articular surfaces' congruency under joint loading.2) Static ligamentous structures, which offer support.3) Through the musculotendinous units, dynamic joint stability is made possible. In order to manage lateral ankle instability, it is essential to comprehend the functional roles of these components. [2] A joint capsule and several ligaments, such as the deltoid ligament, calcaneofibular ligament, anterior talofibular ligament, and posterior talofibular ligament, provide support for this joint. The deltoid ligament provides medial support, whereas the ATFL, PTFL, and CFL support the lateral portion of the ankle. [3]

Due to greater ankle supination, which occurs during plantar flexion and inversion when the ankle joint is less stable, LAS frequently occurs during these movements. [1] When an ankle sprain occurs laterally, the ATFL typically suffers damage before the CFL. Lateral ankle sprains frequently result in concurrent injury to the subtalar joint ligaments and the talocrural joint capsule. [4]

Lateral ankle sprains (LAS) impair adjacent nerve and musculotendinous structures in addition to ligaments. Joint laxity and neuromuscular deficiencies may ensue from this, including decreased nerve conduction velocity, impaired feeling, restricted dorsiflexion range of motion, diminished joint position perception, slower muscle reaction to disturbance of the ankle, and impaired balance. Additionally, aberrant scar tissue production following an injury may result in anterolateral impingement syndrome or sinus tarsi syndrome, which may worsen ankle complex functional impairment. [5]

Either Mechanical Ankle Instability (MAI) or Functional Ankle Instability (FAI) is the cause of Chronic Ankle Instability (CAI). The main cause of MAI is ligament laxity, whereas proprioceptive deficiencies, neuromuscular deficits, postural control deficits, and muscle weakness are the causes of FAI. [1] It has been discovered that long-term sprains affect the sensorimotor system centrally, leading to deficiencies in posture control and balance. This data is carried by afferent nerve fibers, which integrate it with vestibular and visual system inputs to determine coordination and posture control. Changes in this information after an injury increases the risk of recurrent sprains by causing joint instability and functional limitations. [6]

Dynamic balance is essential for everyday tasks like walking, running, and stair climbing, as well as for sports activities It depends on the somatosensory, vestibular, and visual systems, all of which can be compromised by aging, disease, musculoskeletal injuries, and head trauma. Such impairments can reduce a person's ability to engage in dynamic activities, thus hindering normal daily function. [7]

People who have CAI frequently have mechanical deficits, sensorimotor deficits, or a combination of both. They may experience heightened pain, reduced physiological and accessory joint motion, tenderness in ligaments, and weakened foot and ankle strength. [8] Restrictions in joint range of motion, neuromuscular dysfunction, and diminished physical activities are common characteristics of CAI and have been identified as potential causes of muscle atrophy. Clinical indicators of muscular atrophy that are commonly seen in CAI patients include weakness, changed gait patterns, and increased vulnerability to injuries. [9] In the active and neural subsystems, the plantar intrinsic foot muscles are essential because they operate as local stabilizers and detect foot deformation immediately. On the other hand, extrinsic foot muscle tendons' orientations show that they can dynamically support and regulate the longitudinal and transverse components of the foot arch. During dynamic activities, these muscles serve as global movers, helping to both absorb and propel forces. [10] Patients with CAI show significant deficits in total extrinsic muscle volume, particularly in the superficial posterior compartment. Furthermore, we noticed that the CAI group may have flexor hallucis longus hypertrophy as a result of compensatory mechanisms. It's important to understand, though, that the reduced physical activity linked to CAI may make muscular atrophy and weakness worse. [11]

During walking, the flexor hallucis longus is known to play a crucial stabilizing role in the medial longitudinal arch and first ray plantar flexor. Studies have found hypertrophy in the flexor hallucis longus and atrophy in the flexor hallucis brevis and flexor hallucis obliquus. Previous studies on CAI have primarily focused on rearfoot mechanics and peroneal dysfunction. Prior studies that relate first ray rigidity to elevated lateral plantar pressure a feature observed in CAI gait patterns support this theory. Over time, the flexor hallucis longus may become hypertrophied due to the increasing strain it experiences during supination stability of the foot and medial longitudinal arch. Conversely, flexor hallucis brevis and flexor hallucis obliqus disuse atrophy may be caused by decreased first ray excursion and force transmission through the first ray. [11] The interplay between intrinsic and extrinsic foot muscles is noted, suggesting that intrinsic muscles provide a stable foundation for gross movement by extrinsic muscles. Conversely, abnormal muscle activity in the Abductor Hallucis (AbH) may indicate neuromuscular dysfunction following lateral ankle sprains (LAS). [12] The muscles proximal to the unstable ankle are commonly weak in patients with chronic ankle instability (CAI). These deficiencies include concentric knee flexion and extension, isometric hip abduction and extension, external rotation, and eccentric hip flexion. Furthermore, distal hallucis weakness and decreased toe-flexion strength have been observed in these patients, as well as decreased volume in the flexor hallucis brevis and adductor hallucis oblique muscles. [13] Following LAS, impairment of tibial nerve is prevalent; up to 83% of patients with decreased nerve conduction following injury have this condition. Given that the tibial nerve innervates the plantar intrinsic foot muscles (IFM) as well as the extrinsic muscles of the posterior compartment, this is clinically significant. People who have both CAI and recent LAS exhibit significant decreases in plantarflexion, hallux flexion, and reduced toe flexion strength. [14]

In order to maintain balance, the extrinsic toe flexors at the ankle joint and all of the toe flexors against the supporting surface through the pads of the planted foot's toes must provide the maximum amount of plantar flexor force. Toe flexor function in balance usually takes into account intrinsic and extrinsic muscles as a single functional unit. In reaction to compressive force, the intrinsic toe flexors actively contract as a group to stabilize the foot.[15] In addition, when postural control is required more frequently, as in single-leg stance and walking, the intrinsic toe flexors contract harder.[16] Perhaps unsurprisingly, research on young adults' toe flexor muscle strength has shown that it improves performance outcomes that depend on dynamic balance, such walking speed.[17], such as quicker 50-meter sprints, greater jump distances, longer single-leg jumps, and higher vertical jumps.[18] Altered foot postures can have a negative impact on toe flexor strength, consequently affecting balance. Certainly, impaired postural balance has been associated with weak toe flexor muscles. [19] Undoubtedly, reduced toe flexor power and compromised balance can raise the risk of harm, especially in older persons. [20]

While research on older populations has indicated a strong relationship between toe flexor strength, particularly the hallux flexor, and balance, it remains uncertain whether this relationship applies universally across all demographic groups. [21] In contrasting populations such as dancers and non-dancers, collegiate dancers exhibited notable differences. In the Y-balance test, dancers outperformed non-dancers in terms of longer reach distances, higher foot arches, and stronger toe flexors. Due to the extensive use of motions in the metatarsophalangeal joint during their routines, dancers have developed intrinsic foot muscles, which is responsible for their increased toe flexor power.[22] Several studies have reported a reduction in both extrinsic and intrinsic muscle strength following lateral ankle sprain.[13 ,14] Studies have demonstrated an improvement in dynamic balance among football athletes following strengthening exercises targeting the big toe.[23] According to certain research, the main hallux flexor's hypertrophy acts as a compensating mechanism. Furthermore, studies have not found significant variations in muscle volume across groups in the peroneal muscles, despite the fact that persons with CAI have the greatest strength deficit in the peroneus muscle when it comes to ankle strength. This disparity raises the possibility that neuromuscular mechanisms, rather than muscle size and related torque-generating capabilities, may be more closely linked to the observed strength impairments in CAI. [11] Therefore, there is a need to investigate whether there is a correlation between hallux flexor strength and dynamic balance in individuals with chronic ankle sprains.

MATERIALS & METHODS

This correlational study was carried out in a period of 12 months from May 2023 to May 2024. Sample size of 25 was estimated. Convenience sampling was used to recruit participants in this study. Patients who came to OPD with history of chronic ankle sprain were given the CAIT questionnaire. Subjects fulfilling the inclusion criteria and exclusion criteria were selected for the study from A. J hospital and research Centre, Mangaluru, Karnataka, India. 40 participants were screened, out of which 15 did not meet the inclusion criteria.

Ethical clearance was obtained from the Institutional ethical committee. Individuals with a lateral ankle sprain ≥ 12 months prior to the study, Individuals who have perceived or episodic giving away, Male and female chronic ankle instability individuals aged between 18-30 years, no current knee or hip injuries that limits function and subjects with CAIT score ≤25 were included in the study. Any known vision deficit other than myopia, hyperopia, or astigmatism, Individuals with neurological or vestibular impairments, Any known somatosensory deficits (other than those present in the ankle for the CAI). Individuals with diabetes mellitus, lumbosacral radiculopathy, soft tissue disorder, and pregnant individuals were excluded in the study. The subjects participating in the study were given patient information sheet containing the study details and the Informed consent was obtained from the subjects prior to the study. Subjects with chronic ankle sprains were recruited using convenience sampling technique. Patients who came to OPD with history of chronic ankle sprain were given the CAIT questionnaire. [24]. Subjects fulfilling the inclusion criteria and exclusion criteria were selected for the study. A brief introduction about the procedure was explained to all the subjects. An initial examination including demographic data such as name, age, gender, BMI respectively was collected prior to the study. Each participant's great toe flexor strength was measured by pinch gauge dynamometer [25] and dynamic balance was assessed using star excursion balance test. [26]

STATISTICAL ANALYSIS

Statistical analysis of the data was performed using SPSS 23.0. The Categorical variables were presented as frequency and percentage. Continuous variables presented as mean and standard deviation. Correlation was performed using Karl-Pearson's coefficient. A p value <0.05 was considered statistically significant.

RESULT

Table 1: Distribution of age

Age	Frequency	Percent
18-21 years	11	55
22-25years	7	35
26-29years	2	10
Total	20	100

The provided data outlines the distribution of age groups within a study sample comprising 20 chronic ankle pain individuals. Majority of participants, constituting 55% of the sample, fall within the 18-21 years. 35% of individuals are represented in the 22-25 years and 10% in the age group 26-29years.

Table 2: Distribution based on gender

Gender	Frequency	Percent
Female	8	40.0
Male	12	60.0
Total	20	100.0

The data presents the gender distribution within a study sample of 20individuals. It shows that 40% are Female, while 60% are Male.

Table 3: Mean and standard deviation of BMI

	N	Minimum	Maximum	Mean	Std. Deviation
BMI	20	16.65	29.40	22.9100	3.49367

The average BMI was 22.91±3.49 with minimum of 16.65 and maximum of 29.40.

Table 4: Median and IQR of Hallux flexor index, SEBT and CAIT score

	Median	IQR
Hallux flexor strength (lbs)	6.1500	(8.35--3.65)
SEBT score	80.6100	(92.8-74.5)

The provided data includes median values and interquartile ranges for hallux flexor strength and SEBT scores. For hallux flexor strength, the median value is 6.1500, with an interquartile range spanning from 3.65 to 8.35. SEBT scores have a median of 80.61 with interquartile range spanning from 74.5 to 92.8.

Table 5: Correlation between Hallux flexor and SEBT

	SEBT	
	r value	p value
Hallux flexor strength (lbs)	-0.160	0.477

The correlation analysis between the Star Excursion Balance Test (SEBT) scores and hallux flexor strength (lbs) yielded a correlation coefficient (r value) of -0.160 and a corresponding p-value of 0.477. p value >0.05 shows correlation is not statistically significant. Therefore, there is insufficient evidence to conclude a significant correlation between SEBT scores and hallux flexor strength based on the provided data.

DISCUSSION

The present study intended to correlate hallux flexor strength and dynamic balance in chronic ankle sprain individuals. We hypothesized that hallux flexor strength would affect dynamic balance in chronic ankle sprains. Hallux flexion is mainly produced by flexor hallucis longus and secondarily by intrinsic muscles. Additionally, it is believed that extrinsic foot muscle contractions indirectly supply local dynamic support, as do the intrinsic foot muscles in the active subsystems. The ability of the extrinsic foot muscle tendons to dynamically support and govern the longitudinal and transverse components of the foot dome is evident from their orientations. When engaging in dynamic activities, these globe movers offer both propulsion and absorption capabilities. [10]

The study's eligibility was checked on 40 individuals. CAIT questionnaire was given and subject fulfilling inclusion and exclusion criteria were taken. Fifteen of them were eliminated because they failed to meet the requirements for inclusion. The study included 25 participants. Majority of participants, constituting 56% of the sample, fall within the 18-21 years. 36% of individuals are represented in the 22-25 years and 8% in the age group 26-29years, the average BMI was 22.15±3.678 with minimum of 15.61 and maximum of 29.40 and 36% are female, while 64% are male. A pinch dynamometer was utilized to measure the seated participants' hallux flexor strength, and the Star excursion balance test was performed to evaluate the dynamic balance of those with chronic ankle sprains. Hallux flexor strength and dynamic balance was then correlated. The data was analyzed and it was found that the correlation analysis between the Star Excursion Balance Test scores and hallux flexor strength shows that it is not statistically significant. The current study's findings indicated that in those with chronic ankle sprains, there is no relationship between dynamic balance and hallux flexor strength.

The study’s first objective was to measure hallux flexor strength and the results revealed a median hallux flexor strength of 6.300 lbs, with an interquartile range spanning from 3.7 to 8.8 lbs. In the CAI group, a study found possible hypertrophy of the flexor hallucis longus and atrophy of the flexor hallucis brevis and flexor hallucis obliquus. Interestingly, there were no variations in muscle volume across the groups in the peroneal muscles. When compared to other ankle strength tests, the CAI group showed the most notable reduction in eversion strength based on effect size. This implies that neuromuscular mechanisms, rather than muscle size and its corresponding torque-generating capacity, may be responsible for the observed eversion strength deficits in both the current and previously reported research. However, it's still unclear if the strength gains seen in earlier research were the result of improved neuromuscular function or muscle growth. [11]

Previous studies supporting the relationship between first ray rigidity and elevated lateral plantar pressure—a characteristic gait pattern in people with CAI. In order to stabilize the supinated foot and medial longitudinal arch, the flexor hallucis longus may be subjected to an elevated load as a result of the laterally deviated plantar pressure seen in CAI. This could eventually lead to the muscle's hypertrophy. The flexor hallucis brevis and flexor hallucis obliquus may experience less stress in response to decreased first ray excursion and lower force transmission through the first ray, which may prevent disuse atrophy.[11]

Results of one study indicate the presence of both intrinsic and extrinsic motor impairments because of the decreased lesser toe and hallux flexion strength, especially when tested in ankle plantar flexion with an increased demand on the intrinsic foot muscles.[8]

A study by Kim YW et al concluded that the toe plantar flexor muscles of the hallux and second toes in the non-faller group were significantly stronger than in the faller group bilaterally, whereas no significant difference in the third or fourth toe plantar flexor strengths was seen between two groups. Toe flexor muscle strength decreases significantly with age, greater toe grip is a strategy for adapting to slippery surface and they found a significantly increased peak pressure and pressure time integral in the hallux on a slippery surface compared to a non -slippery surface and in this study plantar flexor muscle strength of the hallux was greater in the non-faller group than in the faller group. The weakness of the medial toe flexors may be a factor contributing to falls in elderly individuals. The function of the hallux is to control balance and to provide forward propulsion during walking and running, it could affect static or dynamic balance ability [27]

The strength of the hallux plantar flexors and the ankle joint's inversion-eversion range of motion are important factors that determine balance and functional ability in older people, according to a study by Spink MJ et al. The study also found that the hallux plantar flexion strength significantly contributes to these factors, which is consistent with previous research that found links between toe plantar flexor strength and maximum balance range, postural sway, leaning balance tests, and functional measures. Considering that the degree of frontal plane control of the subtalar/ankle joint complex affects the management of mediolateral stability in both unipedal standing and walking. [19]

According to Yoshimoto et al.'s study, even after age adjustments, toe flexion strength of elderly residents of communities was found to be independently connected to dynamic balance ability. Age-related declines in senior people's dynamic balancing skills are well-documented. Furthermore, the physical center of gravity may shift posteriorly due to conditions like spinal kyphosis and flexion contracture of the hip and knee joints, which would lessen the use of the forefoot and weaken the toe flexion strength. However, for senior individuals with minor toe impairment, the impact of therapies that just address toe functions would probably be limited.[21]

According to a study by Chatzistergos PE et al., PGT was used to record one qualitative (pass/fail) and one quantitative (hallux grip force) measure of strength and to look into how they were related to postural sway and the isometric strength of the foot-ankle complex. A significant risk factor for falls is muscle weakness, and prior research has found that distinct muscle groups can independently predict falls. Simultaneously, research conducted on populations free of diabetes discovered that the strength of the hallux plantar flexors or the lesser toe plantar flexors alone could independently predict falls. More precisely, a decrease in hallux grip force was found to be strongly correlated with an increase in postural sway in the population under investigation. This discovery emphasizes the possible application of hallux grip force to detect persons experiencing a decline in their capacity to sustain equilibrium. It seems that the hallux grip force is a task-specific force that is crucial for producing large moments around the first metatarsophalangeal joint. [28]

According to Sarikaya F et al., the experimental and control groups of the study had big toe strengthening percentile development of 40% and 5%, respectively, before and after the test. The big toe is loaded when standing than the heel and heads of the five metatarsals combined. It has been found that as walking speed increases, pressure increases and shifts to the medial region of the foot. The big toe's mobility and stability are essential for the foot to absorb and regulate shock as it touches the ground, stabilize the stride, and support propulsion. The research indicates that there is a positive correlation between improvement of big toe strength and vertical leap and tapping performances, with the big toe being identified as the location that contributes the most to this development. However, only in the two-leg vertical jump performance was this link determined to be meaningful. The muscles of the foot flexors play a crucial role in maintaining both static and dynamic balance during the action. The part of the foot that supports the body when standing and moving is the sole. The foot flexor muscles are also crucial during the posture phase. [23]

According to a systematic review conducted by Quinlan S. et al., the overall implications of the examined research are that an increase in toe flexor strength improves both static and dynamic balance in the population of older adults. In particular, there is evidence that supports up the recommendation that individuals in this population group engage in a progressive resistance strengthening exercise program that focuses on their toe flexors. Every one of the ten toe flexor muscles helps the foot move both when it is in contact with a supportive surface and when it is free to move, when standing upright, the toe flexors' timely and sufficient production of a plantarflexor torque stops the center of mass from anteriorly shifting beyond the base of support. The toe flexors' role in balance usually takes into account the extrinsics and intrinsics working together as a functional unit. [29]

We found no connection between dynamic balance and hallux flexor strength in this investigation. This lack of correlation may stem from previous studies that primarily focused on older populations. A number of variables, including as spinal kyphosis and flexion contracture of the hip and knee joints, are associated with reduced toe flexor strength in these cohorts. These ailments have the potential to cause a posterior shift in the body's center of gravity, which lowers forefoot usage and weakens toe flexion strength. However, our study examined a younger demographic, where such postural changes are typically not present. Ultrasonic assessments of the foot muscles in people with CAI have been investigated in previous research and discovered flexor hallucis longus hypertrophy. This finding's rationale is that the laterally deviated plantar pressure seen in CAI may stabilize the medial longitudinal arch and supinated foot while increasing the strain on the flexor hallucis longus. Over time, this increasing stress may cause the flexor hallucis longus to hypertrophy. These elements could have a role in the absence of association found in our investigation.

Given the multitude of factors affecting dynamic balance in people with chronic recurrent ankle sprains, it's critical to take into consideration all relevant factors. When considering reduced muscle strength, both extrinsic and intrinsic foot muscles play crucial roles as they collaborate in function. Numerous ultrasonic studies have highlighted the hypertrophy of the main hallux flexor, the flexor hallucis longus, attributed to laterally deviated pressure. Additionally, these studies have indicated atrophy in the intrinsic muscles of the hallux. This underscores the need for further exploration, with additional studies warranted to investigate the correlation between hallux flexors and dynamic balance in individuals with chronic ankle sprains. The study's major shortcoming was its limited sample size. And the inclusion of only ages 18-30 years prevents the generalization of the result to others.

CONCLUSION

This study concludes that in people with chronic ankle sprains, there is no correlation between dynamic balance and hallux flexor strength.

Declaration by Authors

Ethical Approval: Approved

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REFERENCES

1. Kobayashi T, Gamada K. Lateral ankle sprain and chronic ankle instability: a critical review. Foot & ankle specialist. 2014 Aug;7(4):298-326
2. Lundberg A, Goldie I, Kalin BO, Selvik G. Kinematics of the ankle/foot complex: plantarflexion and dorsiflexion. Foot & ankle. 1989 Feb;9(4):194-200.
3. Burks RT, Morgan J. Anatomy of the lateral ankle ligaments. The American journal of sports medicine. 1994 Jan;22(1):72-7.
4. Hertel J. Functional anatomy, pathomechanics, and pathophysiology of lateral ankle instability. Journal of athletic training. 2002 Oct;37(4):364.
5. Hertel J. Functional instability following lateral ankle sprain. Sports medicine. 2000 May; 29:361-71.
6. Alghadir AH, Iqbal ZA, Iqbal A, Ahmed H, Ramteke SU. Effect of chronic ankle sprain on pain, range of motion, proprioception, and balance among athletes.
7. Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. Journal of orthopaedic & sports physical therapy. 1998 May;27(5):356-60.
8. Fraser JJ, Koldenhoven RM, Jaffri AH, Park JS, Saliba SF, Hart JM, Hertel J. Foot impairments contribute to functional limitation in individuals with ankle sprain and chronic ankle instability. Knee Surgery,

Sports Traumatology, Arthroscopy. 2020 May;28(5):1600-10.
9. Hertel J. Sensorimotor deficits with ankle sprains and chronic ankle instability. Clinics in sports medicine. 2008 Jul 1;27(3):353-70.
10. McKeon PO, Hertel J, Bramble D, Davis I. The foot core system: a new paradigm for understanding intrinsic foot muscle function. British journal of sports medicine. 2015 Mar 1;49(5):290-.
11. Feger MA, Snell S, Handsfield GG, Blemker SS, Wombacher E, Fry R, Hart JM, Saliba SA, Park JS, Hertel J. Diminished foot and ankle muscle volumes in young adults with chronic ankle instability. Orthopaedic journal of sports medicine. 2016 Jun 16;4(6):2325967116653719.
12. Watanabe T, Takabayashi T, Kikumoto T, Kikuchi Y, Suzuki S, Hiratsuka S, Kubo M. Differences in abductor hallucis activity during running in individuals with chronic ankle instability and copers. Gait & Posture. 2024 Feb 1; 108:22-7.
13. Hertel J, Corbett RO. An updated model of chronic ankle instability. Journal of athletic training. 2019 Jun 1;54(6):572-88.
14. Fraser JJ, Koldenhoven R, Hertel J. Ultrasound measures of intrinsic foot muscle size and motor activation following lateral ankle sprain and chronic ankle instability. A cross-sectional study. medRxiv. 2020 Aug 4:2020-07.
15. Kelly LA, Lichtwark G, Cresswell AG. Active regulation of longitudinal arch compression and recoil during walking and running. Journal of the Royal Society Interface. 2015 Jan 6;12(102):20141076.
16. Kelly LA, Kuitunen S, Racinais S, Cresswell AG. Recruitment of the plantar intrinsic foot muscles with increasing postural demand. Clinical biomechanics. 2012 Jan 1;27(1):46-51.
17. Kaneko R, Fujisawa S, Sasaki M. Influence of toe flexer muscle strength training on floor reaction force during maximum speed walk. Rigakuryoho Kagaku. 2009;24(3): 411-6.
18. Hashimoto T, Sakuraba K. 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. Journal of physical therapy science. 2014;26(3):373-6.
19. Spink MJ, Fotoohabadi MR, Wee E, Hill KD, Lord SR, Menz HB. Foot and ankle strength, range of motion, posture, and deformity are associated with balance and functional ability in older adults. Archives of physical medicine and rehabilitation. 2011 Jan 1;92(1):68-75.
20. Kobayashi R, Hosoda M, Minematsu A, Sasaki H, Maejima H, Tanaka S, Kanemura N, Matsuo A, Shirahama K, Ueda T, Kamoda C. Effects of toe grasp training for the aged on spontaneous postural sway. Journal of physical therapy science. 1999;11(1):31-4.
21. Yoshimoto Y, Oyama Y, Tanaka M, Sakamoto A. Toe functions have little effect on dynamic balance ability in elderly people. Journal of physical therapy science. 2017;29(1):158-62.
22. Matsumoto M, Yamamoto K. Foot arch height, toe flexor strength, and dynamic balance ability in collegiate female dancers and non-dancers. Journal of Physical Therapy Science. 2022;34(2):135-9.
23. Sarikaya F, Sahin M. The Effect of Big Toe Strength Development on Some Athletic Performance Parameter in Young Male Footballers. Pakistan Journal of Medical & Health Sciences. 2022 Apr 8;16(02):997
24. Vuurberg G, Kluit L, van Dijk CN. The Cumberland Ankle Instability Tool (CAIT) in the Dutch population with and without complaints of ankle instability. Knee Surgery, Sports Traumatology, Arthroscopy. 2018 Mar; 26:882-91
25. Shamus J, Shamus E, Gugel RN, Brucker BS, Skaruppa C. The effect of sesamoid mobilization, flexor hallucis strengthening, and gait training on reducing pain and restoring function in individuals with hallux limitus: a clinical trial. Journal of Orthopaedic & Sports Physical Therapy. 2004 Jul;34(7):368-76)
26. Powden CJ, Dodds TK, Gabriel EH. The reliability of the star excursion balance test and lower quarter y-balance test in healthy adults: a systematic review. International journal of sports physical therapy. 2019 Sep;14(5):683.
27. Kim YW, Kwon OY, Cynn HS, Weon JH, Yi CH, Kim TH. Comparison of toe plantar flexors strength and balancing ability between elderly fallers and non-fallers. Journal of Physical Therapy Science. 2011;23(1):127-32.

28. Chatzistergos PE, Healy A, Naemi R, Sundar L, Ramachandran A, Chockalingam N. The relationship between hallux grip force and balance in people with diabetes. Gait & posture. 2019 May 1; 70:109-15
29. Quinlan S, Yan AF, Sinclair P, Hunt A. The evidence for improving balance by strengthening the toe flexor muscles: A systematic review. Gait & Posture. 2020 Sep 1; 81:56-66.

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