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Effect Of Strength And Range Of Motions Of Ankle Joint On Balance In Healthy Population Aged 60-80 Years- A Descriptive Study.

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Abstract

Background: Maintaining balance and mobility is crucial for the overall well-being of the elderly population. The ankle joint plays a vital role in providing stability and facilitating movement. Understanding the relationship between ankle strength, range of motion, and balance can provide valuable insights into promoting healthy ageing and reducing the risk of falls.
Methodology: This descriptive study focused on a sample of 200 healthy individuals aged 60-80 years. Gender distribution was assessed, and strength measurements were taken for dorsiflexion, plantarflexion, inversion, and eversion movements of the ankle. The range of motion was evaluated for each movement. Static balance was measured, and the Pearson correlation coefficient was used to analyse the relationships between strength, range of motion, and balance.
Result: The gender distribution showed a higher representation of males (62%) compared to females (38%) in the study. Significant positive correlations were observed between ankle strength and range of motion in all movements (dorsiflexion, plantarflexion, inversion, and eversion). Furthermore, a higher range of motion was associated with improved static balance. These findings highlight the importance of ankle strength and flexibility in maintaining stability and balance in the elderly population.
Conclusion: The study demonstrates significant associations between ankle strength, range of motion, and static balance in healthy

individuals aged 60-80 years. Enhancing ankle strength and mobility can play a crucial role in promoting balance and reducing the risk of falls among the elderly. Further research is warranted to explore these relationships in broader populations and clinical settings, leading to targeted interventions for improving mobility and reducing fall-related injuries.

Keywords: Ankle joint, Strength, Range of motion, Balance, Healthy population, Elderly, Descriptive study, Pearson correlation coefficient, Mobility, Fall risk.

INTRODUCTION:

The decline in physical function and balance is a common consequence of ageing, often leading to an increased risk of falls and subsequent injuries in the elderly population(1). Maintaining optimal balance is crucial for maintaining independence and preventing the loss of functional abilities among older individuals(2). Ankle joint function plays a significant role in maintaining stability and postural control, as it serves as a primary contributor to weight-bearing and locomotion(3). The present study aims to investigate the effect of ankle joint strength and range of motion on balance in a healthy population aged 60-80 years. Understanding the relationship between ankle joint characteristics and balance can provide valuable insights into developing targeted interventions and exercise programs to improve balance and reduce the risk of falls among older adults(4).

Numerous studies have demonstrated the significance of ankle strength and range of motion in maintaining balance(5–8). Age-related changes, such as muscle weakness and reduced joint flexibility, may impact ankle function and subsequently affect balance control. Impaired ankle strength can compromise the ability to generate sufficient force during weight-bearing activities, leading to instability and an increased risk of falls(9). Similarly, a limited ankle range of motion can restrict movement, affecting gait patterns and overall postural stability(10). While several studies have explored the association between ankle joint characteristics and balance in older adults, there is still a need for further investigation, especially within a specific age range and healthy population(11–16). This descriptive study aims to fill this research gap by assessing ankle joint strength and range of motion with balance parameters in individuals aged 60-80 years without any existing musculoskeletal or neurological conditions. The study will recruit a representative sample of healthy individuals aged 60-80 years, ensuring both male and female participants are included. The findings from this study are expected to provide valuable insights into the relationship between ankle joint characteristics and balance in the targeted population. The results may contribute to the development of evidence-based interventions aimed at improving balance and reducing fall risk in older adults. Ultimately, this research has the potential to enhance the quality of life and independence among older individuals, promoting healthy ageing within the community.

OBJECTIVE

The objectives of this study revolve around quantitatively assessing ankle joint characteristics, including strength and range of motion, and their relationship with static balance. By measuring these variables and examining their correlations, the study aims to provide insights into the impact of ankle joint function on balance in the targeted population of healthy individuals aged 60-80 years.

METHODOLOGY

The study aimed to examine the effect of ankle joint strength and range of motion on balance in a healthy population aged 60-80 years. The study followed a descriptive design, correlating age-related ankle joint characteristics with balance components in the elderly. The data collection procedures were conducted after obtaining the necessary permissions. The study was carried out in two settings: the Community Physiotherapy Outpatient Department (OPD) and community-based settings. Community-based settings provided access to community-dwelling older adults, who actively participated in the study. Primary care centres facilitated data collection, allowing for the assessment of ankle joint characteristics in older individuals. The outcome measures were executed at the site of data collection, fostering a close relationship between the subjects and investigators. The data collected were then evaluated, compiled, and analysed to determine correlations between outcome measures among the elderly population. The study population consisted of healthy individuals aged 60-80 years. Both male and female participants were included, irrespective of gender. The target population was selected from the age group of 60 to 80 years to form the study population. Only healthy older adults were included in the measurements conducted in this study. The study duration spanned 18 months, starting from the approval of the research study by the board until the submission of the final results and compilation to the university. This duration encompassed the entire process, including data collection, analysis, and report preparation.

Inclusion Criteria:
- Subjects aged between 60 to 80 years.
- Both genders.
- Physiologically healthy individuals with vital signs within normal limits.

Exclusion Criteria:
- Recent trauma/fracture of the lower extremity.
- Lower extremity replacement surgery (e.g., total hip replacement, total knee replacement, amputation).
- Neurological disorders.
- Vestibular disorders.
- Compromised audio or visual function.
- Foot disorders (e.g., calcaneal spur, plantar fasciitis).

The study included a total of 200 participants who underwent the assessment protocol and data compilation. Before the measurements, the purpose and procedure of the study were explained to the subjects, and informed consent was obtained. Anthropometric data, such as height and weight, were recorded. The study included both male and female participants aged 60-80 years, with 50 subjects in each age group. Ankle muscle strength was assessed using a Jamar hand-held dynamometer, with measurements recorded in kilograms. The dynamometer featured a dual scale readout displaying isometric force from 0-90 kg (0-200 lb). Ankle strength and range of motion measurements were performed in supine and prone positions, respectively. The active range of motion was measured using a full-circle goniometer. After a 10-minute rest period, participants were asked to stand on one limb while the other limb was raised, maintaining focus on a spot at eye level. The time taken to maintain balance on one limb was recorded using a stopwatch, with specific criteria for ending the test. This single-leg stance test was performed twice, with the best recording considered for data analysis. A 5-minute rest period was given between the two tests. All outcome measures, including ankle strength, range of motion, and balance performance, were compiled and entered into an Excel sheet for further analysis.

RESULT

GENDER	MALE	FEMALE
N -200	124(62%)	76(38%)

TABLE NO 1 -SHOWS THE GENDR RATIO IN THE STUDY

Table 1 displays the gender distribution in the study, indicating the number of male and female participants. Out of a total sample size of 200 participants, 124 individuals (62%) were male, while 76 individuals (38%) were female. This table provides an overview of the gender ratio and highlights the representation of males and females in the study

TABLE NO 2 - COMPARING THE STRENGTH LEVEL AND ITS RELATIONS WITH THE RANGE OF MOTION (Pearson correlation coefficient)

GROUP	RIGHT DORSIFLEXION (KG)	LEFT DORSIFLEXION (KG)	RIGHT PLANTARFLEXION (KG)	LEFT PLANTARFLEXION (KG)	RIGHT INVERSION (KG)	LEFT INVERSION (KG)	RIGHT EVERSION (KG)	LEFT EVERSION (KG)
RIGHT DORSIFLEXION (ROM)	.554**	.600**	.369**	.339**	.324**	.308**	.235**	.293**
LEFT DORSIFLEXION (ROM)	.595**	.642**	.432**	.398**	.380**	.363**	.281**	.377**
RIGHT PLANTARFLEXION (ROM)	.587**	.643**	.384**	.472**	.477**	.452**	.385**	.420**
LEFT PLANTARFLEXION (ROM)	.562**	.613**	.378**	.486**	.488**	.469**	.407**	.444**
RIGHT INVERSION (ROM)	.586**	.590**	.237**	.336**	.396**	.396**	.293**	.391**
LEFT INVERSION (ROM)	.560**	.573**	.262**	.364**	.384**	.393**	.310**	.384**
RIGHT EVERSION (ROM)	.681**	.716**	.452**	.556**	.543**	.570**	.557**	.590**
LEFT EVERSION (ROM)	.697**	.727**	.469**	.579**	.558**	.591**	.575**	.634**

** Correlation is significant at the 0.01 level (2-tailed).

The results of comparing the strength level and its relationship with the range of motion (ROM) are presented in Table 2. The analysis aimed to assess the correlation between the strength of different ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) in kilograms and their respective range of motion.

Examining the relationship between dorsiflexion strength and dorsiflexion range of motion, the results showed positive correlations. The correlation coefficients for right dorsiflexion strength and dorsiflexion ROM were 0.554** and 0.600** respectively, while for left dorsiflexion strength and dorsiflexion ROM, the correlation coefficients were 0.595** and 0.642** respectively. These findings suggest that greater dorsiflexion strength is associated with increased dorsiflexion range of motion.

In terms of plantarflexion strength and plantarflexion ROM, positive correlations were observed. The correlation coefficients for right plantarflexion strength and plantarflexion ROM were 0.587** and 0.643** respectively, while for left plantarflexion strength and plantarflexion ROM, the correlation coefficients were 0.562** and 0.613** respectively. These results indicate that higher plantarflexion strength tends to be related to greater plantarflexion ROM.

Analysing the relationship between inversion strength and inversion ROM, moderate positive correlations were found. The correlation coefficients for right inversion strength and inversion ROM were 0.586** and 0.590** respectively, while for left inversion strength and inversion ROM, the correlation coefficients were 0.560** and 0.573** respectively. These findings suggest that greater inversion strength is associated with increased inversion ROM to some extent.

Regarding eversion strength and eversion ROM, strong positive correlations were observed. The correlation coefficients for right eversion strength and eversion ROM were 0.681** and 0.716** respectively, while for left eversion strength and eversion ROM, the correlation coefficients were 0.697** and 0.727** respectively. These results indicate that higher eversion strength is correlated with greater eversion ROM.

The results from Table 2 demonstrate significant associations between the strength of different ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) and their respective range of motion. Higher strength levels tend to be correlated with an increased range of motion in these movements, emphasizing the relationship between strength and mobility in the ankle joint.

TABLE NO 3 - COMPARING THE EFFECT OF RANGE OF MOTION ON BALANCE (Pearson correlation coefficient)

GROUP	STATIC BALANCE EYES OPEN	STATIC BALANCE EYES CLOSED
RIGHT DORSIFLEXION (ROM)	.629**	.547**
LEFT DORSIFLEXION (ROM)	.651**	.582**
RIGHT PLANTARFLEXION (ROM)	.629**	.590**
LEFT PLANTARFLEXION (ROM)	.584**	.568**
RIGHT INVERSION (ROM)	.507**	.506**
LEFT INVERSION (ROM)	.504**	.510**
RIGHT EVERSION (ROM)	.727**	.704**
LEFT EVERSION (ROM)	.740**	.723**

** Correlation is significant at the 0.01 level (2-tailed).

The results of comparing the effect of a range of motion (ROM) on balance, using Pearson correlation coefficients, revealed interesting findings. When examining the relationship between ROM of dorsiflexion and static balance with eyes open, a strong positive correlation was observed. The correlation coefficient for right dorsiflexion and static balance with eyes open was 0.629**, indicating a significant association. Similarly, the correlation coefficient for left dorsiflexion and static balance with eyes open was 0.651**, also demonstrating a significant relationship.

Furthermore, the analysis of ROM of plantarflexion and its impact on static balance yielded noteworthy results. Both right and left plantarflexion exhibited positive correlations with static balance, regardless of whether the eyes were open or closed. The correlation coefficients for right plantarflexion and static balance were 0.629** and 0.584** with eyes open and closed, respectively. Likewise, the correlation coefficients for left plantarflexion and static balance were 0.590** and 0.568** with eyes open and closed, respectively. These findings highlight the importance of plantarflexion ROM in maintaining balance.

Moving on to the analysis of ROM of inversion and eversion, it was found that both motions significantly correlated with static balance. The correlation coefficients for right inversion and static balance were 0.507** and 0.504** with eyes open and closed, respectively. Similarly, the correlation coefficients for left inversion and static balance were 0.506** and 0.510** with eyes open and closed, respectively. These results emphasize the influence of inversion and eversion ROM on static balance.

Lastly, the strongest correlations were observed between ROM of eversion and static balance, regardless of eye condition. The correlation coefficients for right eversion and static balance were 0.727** and 0.740** with eyes open and closed, respectively. Similarly, the correlation coefficients for left eversion and static balance were 0.704** and 0.723** with eyes open and closed, respectively. These findings suggest a substantial relationship between eversion ROM and maintaining balance.

The results indicate significant associations between the range of motion in various ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) and static balance. These findings highlight the importance of ankle flexibility and mobility in maintaining proper balance and stability.

TABLE NO 4 - COMPARING THE EFFECT OF STRENGTH ON BALANCE (Pearson correlation coefficient)

GROUP	STATIC BALANCE EYES OPEN	STATIC BALANCE EYES CLOSED
RIGHT DORSIFLEXION (KG)	.725**	.680**
LEFT DORSIFLEXION (KG)	.737**	.708**
RIGHT PLANTARFLEXION(KG)	.435**	.474**
LEFT PLANTARFLEXION(KG)	.462**	.597**
RIGHT INVERSION(KG)	.433**	.434**
LEFT INVERSION(KG)	.453**	.501**
RIGHT EVERSION(KG)	.412**	.471**
LEFT EVERSION(KG)	.458**	.525**

The results of comparing the effect of strength on balance, using Pearson correlation coefficients, are presented in Table 6. The analysis examined the relationship between strength in different ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) and static balance with eyes open and closed.

When assessing the relationship between dorsiflexion strength (in kilograms) and static balance, strong positive correlations were observed. The correlation coefficients for right dorsiflexion strength and static balance were 0.725** and 0.680** with eyes open and closed, respectively. Similarly, the correlation coefficients for left dorsiflexion strength and static balance were 0.737** and 0.708** with eyes open and closed, respectively. These findings suggest that greater dorsiflexion strength is associated with improved static balance.

In terms of plantarflexion strength, the results indicated positive correlations with static balance. The correlation coefficients for right plantarflexion strength and static balance were 0.435** and 0.474** with eyes open and closed, respectively. Likewise, the correlation coefficients for left plantarflexion strength and static balance were 0.462** and 0.597** with eyes open and closed, respectively. These results imply that higher plantarflexion strength may contribute to enhanced static balance.

Examining the relationship between inversion strength and static balance, moderate positive correlations were observed. The correlation coefficients for right inversion strength and static balance were 0.433** and 0.434** with eyes open and closed, respectively. Similarly, the correlation coefficients for left inversion strength and static balance were 0.453** and 0.501** with eyes open and closed, respectively. These findings suggest that greater inversion strength is associated with improved static balance to some extent.

Finally, the analysis of eversion strength revealed positive correlations with static balance. The correlation coefficients for right eversion strength and static balance were 0.412** and 0.471** with eyes open and closed, respectively. Similarly, the correlation coefficients for left eversion strength and static balance were 0.458** and 0.525** with eyes open and closed, respectively. These results indicate that higher eversion strength may contribute to better static balance.

The results demonstrate significant associations between strength in different ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) and static balance. Greater strength in these movements tends to be correlated with improved static balance, emphasizing the importance of ankle strength for maintaining stability and balance.

DISCUSSION

The discussion section of this research paper provides an analysis and interpretation of the findings related to the effect of strength and range of motions of the ankle joint on balance in a healthy population aged 60-80 years. Table 1 presents the gender distribution in the study, indicating the number of male and female participants out of a total sample size of 200. The table shows that 124 individuals (62%) were male, while 76 individuals (38%) were female. This information provides an overview of the gender ratio and highlights the representation of males and females in the study. Table 2 focuses on comparing the strength level of different ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) with their respective range of motion (ROM). The table presents the correlation coefficients (Pearson correlation coefficient) between the strength in kilograms and the ROM for each ankle movement. The results show positive correlations between strength and ROM for all ankle movements. Regarding dorsiflexion, both right and left dorsiflexion strength exhibited positive correlations with dorsiflexion ROM. The correlation coefficients were 0.554** and 0.600** for right dorsiflexion strength and ROM, respectively, while for left dorsiflexion strength and ROM, the correlation coefficients were 0.595** and 0.642**. These findings suggest that greater dorsiflexion strength is associated with increased dorsiflexion ROM. Similarly, for plantarflexion, positive correlations were observed between strength and ROM. The correlation coefficients for right plantarflexion strength and ROM were 0.587** and 0.643**, respectively, while for left plantarflexion strength and ROM, the correlation coefficients were 0.562** and 0.613**. These results indicate that higher plantarflexion strength tends to be related to greater plantarflexion ROM. The analysis also revealed moderate positive correlations between inversion strength and inversion ROM. The correlation coefficients for right inversion strength and ROM were 0.586** and 0.590**, respectively, while for left inversion strength and ROM, the correlation coefficients were 0.560** and 0.573**. These findings suggest that greater inversion strength is associated with increased inversion ROM to some extent.

Furthermore, strong positive correlations were observed between eversion strength and eversion ROM. The correlation coefficients for right eversion strength and ROM were 0.681** and 0.716**, respectively, while for left eversion strength and ROM, the correlation coefficients were 0.697** and 0.727**. These results indicate that higher eversion strength is correlated with greater eversion ROM. The results from Table 2 demonstrate significant associations between the strength of different ankle movements and their respective range of motion. Higher strength levels tend to be correlated with an increased range of motion in these movements, highlighting the relationship between strength and mobility in the ankle joint. Table 3 focuses on comparing the effect of a range of motion (ROM) on balance using Pearson correlation coefficients. The analysis examined the relationship between ROM of different ankle movements and static balance with eyes open and closed. When assessing the relationship between dorsiflexion ROM and static balance with eyes open, a strong positive correlation was observed. The correlation coefficient for right dorsiflexion ROM and static balance was 0.629**, indicating a significant association. Similarly, the correlation coefficient for left dorsiflexion ROM and static balance was 0.651**, demonstrating a significant relationship. Regarding plantarflexion ROM, positive correlations were found with static balance regardless of whether the eyes were open or closed. The correlation coefficients for right plantarflexion ROM and static balance were 0.629** and 0.584** with eyes open and closed, respectively. Likewise, the correlation coefficients for left plantarflexion ROM and static balance were 0.590** and 0.568** with eyes open and closed, respectively. Analysing the relationship between inversion ROM and static balance, both right and left inversion showed significant correlations. The correlation coefficients for right inversion ROM and static balance were 0.507** and 0.504** with eyes open and closed, respectively. Similarly, the correlation coefficients for left inversion ROM and static balance were 0.506** and 0.510** with eyes open and closed, respectively. Lastly, the strongest correlations were observed between eversion ROM and static balance regardless of an eye condition. The correlation coefficients for right eversion ROM and static balance were 0.727** and 0.740** with eyes open and closed, respectively. Similarly, the correlation coefficients for left eversion ROM and static balance were 0.704** and 0.723** with eyes open and closed, respectively. The results indicate significant associations between the range of motion in various ankle movements and static balance. These findings emphasize the importance of ankle flexibility and mobility in maintaining proper balance and stability.

CONCLUSION

In conclusion, the findings of this descriptive study on the effect of strength and range of motion of the ankle joint on balance in a healthy population aged 60-80 years provide valuable insights. The results from the study indicate significant associations between ankle strength, range of motion, and static balance. The analysis of strength in different ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) revealed positive correlations with their respective range of motion. Higher strength levels were found to be associated with an increased range of motion, highlighting the importance of ankle strength for mobility and flexibility. Furthermore, the study found that the range of motion in various ankle movements (dorsiflexion, plantarflexion, inversion, and eversion) significantly correlated with static balance. A greater range of motion in these movements was associated with improved static balance, indicating the influence of ankle flexibility on maintaining balance and stability. These findings underscore the importance of maintaining optimal ankle strength and range of motion for promoting balance and reducing the risk of falls in the elderly population. Enhancing ankle strength and flexibility through targeted exercises and interventions may prove beneficial in improving overall balance and reducing the likelihood of balance-related injuries. It is important to note that this study focused on a healthy population aged 60-80 years, and the results may not be directly applicable to individuals with underlying health conditions or outside this age range. Further research is needed to explore the impact of ankle strength and range of motion on balance in broader populations and specific clinical contexts. Overall, this study contributes to the existing body of knowledge regarding the relationship between ankle strength, range of motion, and balance, emphasizing the significance of ankle joint health in promoting functional mobility and reducing fall risk in older adults.

REFERENCES

1. Howe TE, Rochester L, Jackson A, Banks PM, Blair VA. Exercise for improving balance in older people. Cochrane Database Syst Rev. 2007;
2. Onambele GL, Maganaris CN, Mian OS. Neuromuscular and balance responses to flywheel inertial versus weight training in older persons. J Biomech [Internet]. 2008;41. Available from: https://doi.org/10.1016/j.jbiomech.2008.09.004
3. Menz HB, Morris ME, Lord SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 2005;60(12):1546–52.
4. Jenkins ND, Buckner SL, Bergstrom HC. Reliability and relationships among handgrip strength, leg extensor strength and power, and balance in older men. Exp Gerontol [Internet]. 2014;58. Available from: https://doi.org/10.1016/j.exger.2014.07.007
5. Justine M, Ruzali D, Hazidin E, Said A, Bukry SA, Manaf H. Range of motion, muscle length, and balance performance in older adults with normal, pronated, and supinated feet. J Phys Ther Sci. 2016;28(3):916–22.
6. Pamukoff DN, Haakonssen EC, Zaccaria JA. The effects of strength and power training on single-step balance recovery in older adults: a preliminary study. Clin Interv Aging. 2014;9.
7. Holviala JH, Sallinen JM, Kraemer WJ. Effects of strength training on muscle strength characteristics, functional capabilities, and balance in middle-aged and older women. J Strength Cond Res. 2006;20.
8. 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. Arch Phys Med Rehabil [Internet]. 2011;92(1):68–75. Available from: http://dx.doi.org/10.1016/j.apmr.2010.09.024
9. Papalia GF, Papalia R, Balzani LAD, Torre G, Zampogna B, Vasta S, et al. The effects of physical exercise on balance and prevention of falls in older people: A systematic review and meta-analysis. Vol. 9, Journal of Clinical Medicine. MDPI; 2020. p. 1–19.
10. Laubach KJL. A Home-based Exercise Program for the Foot and Ankle to Improve Balance, Muscle Performance and Flexibility in Community Dwelling Older Adults: A Pilot Study. Int J Phys Med Rehabil. 2013;01(03).

11. Buchner DM, Cress ME, Lateur BJ, Esselman PC, Margherita AJ, Price R, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. J Gerontol Ser A [Internet]. 1997;52. Available from: https://doi.org/10.1093/gerona/52A.4.M218
12. Martins AC, Santos C, Silva C, Baltazar D, Moreira J, Tavares N. Does modified Otago Exercise Program improves balance in older people? A systematic review. Prev Med Rep [Internet]. 2018 May;11:231–9. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2211335518301116
13. Lee DK, Kang MH, Lee TS, Oh JS. Relationships among the Y balance test, Berg Balance Scale, and lower limb strength in middle-aged and older females. Braz J Phys Ther. 2015 May;19(3):227–34.
14. Orr R, Vos NJ, Singh NA. Power training improves balance in healthy older adults. J Gerontol A Biol Sci Med Sci [Internet]. 2006;61. Available from: https://doi.org/10.1093/gerona/61.1.78
15. Kahle N, Tevald MA. Core muscle strengthening's improvement of balance performance in community-dwelling older adults: A pilot study. J Aging Phys Act. 2014 May;22(1):65–73.
16. Bean JF, Herman S, Kiely DK. Increased Velocity Exercise Specific to Task (InVEST) training: a pilot study exploring effects on leg power, balance, and mobility in community-dwelling older women. J Am Geriatr Soc [Internet]. 2004;52. Available from: https://doi.org/10.1111/j.1532-5415.2004.52222.x
17. Williams GN, Higgins MJ, Lewek MD. Aging skeletal muscle: physiologic changes and the effects of training. Physical therapy. 2002 Jan 1;82(1):62-8.
18. Hall CM, Brody LT. Balance impairment in: therapeutic exercise: moving toward function. Philadelphia, L & W. 1999.
19. Nashner LM. Sensory, neuromuscular, and biomechanical contributions to human balance. InProceeding of APTA Forum, Tennessee, 1989 1989 .
20. Daubney ME, Culham EG. Lower-extremity muscle force and balance performance in adults aged 65 years and older. Physical therapy. 1999 Dec 1;79(12):1177-85.
21. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. Journal of gerontology. 1991 May 1;46(3):M69-76.
22. Grimston SK, Nigg BM, Hanley DA, Engsberg JR. Differences in ankle joint complex range of motion as a function of age. Foot & ankle. 1993 May;14(4):215-22 86
23. Guccione AA, Avers D, Wong R. Geriatric physical therapy-ebook. Elsevier Health Sciences; 2011 Mar 7.
24. Grimston SK, Nigg BM, Hanley DA, Engsberg JR. Differences in ankle joint complex range of motion as a function of age. Foot & ankle. 1993 May;14(4):215-22
25. Hartsell HD, Spaulding SJ. Effectiveness of external orthotic support on passive soft tissue resistance of the chronically unstable ankle. Foot & ankle international. 1997 Mar;18(3):
26. Cavanagh PR. Plantar soft tissue thickness during ground contact in walking. Journal of biomechanics. 1999 Jun 1;32(6):623-8.
27. Hsu CC, Tsai WC, Chen CP, Shau YW, Wang CL, Chen MJ, Chang KJ. Effects of aging on the plantar soft tissue properties under the metatarsal heads at different impact velocities. Ultrasound in medicine & biology. 2005 Oct 1;31(10):1423-9.
28. Kwan RL, Zheng YP, Cheing GL: The effect of aging on the biomechanical properties of plantar soft tissues. Clin Biomech2010; 25: 601–605.
29. Cheng JW, Tsai WC, Yu TY. Gender-related effect of aging on the sonographic appearance of plantar fascia. Journal of Musculoskeletal Pain. 2014 Mar 1;22(1):33-7.
30. Menz HB, Fotoohabadi MR, Munteanu SE, Zammit GV, Gilheany MF. Plantar pressures and relative lesser metatarsal lengths in older people with and without forefoot pain. Journal of Orthopaedic Research. 2013 Mar;31(3):427-33.
31. Mickle KJ, Munro BJ, Lord SR, Menz HB, Steele JR. Foot pain, plantar pressures, and falls in older people: a prospective study. Journal of the American Geriatrics Society. 2010 Oct;58(10):1936-40.
32. Hamerman D. Biology of the aging joint. Clinics in geriatric medicine. 1998 Aug 1;14(3):417-34.
33. James B, Parker AW. Active and passive mobility of lower limb joints in elderly men and women. American journal of physical medicine & rehabilitation. 1989 Aug 1;68(4):162-7.
34. Nigg BM, Fisher V, Allinger TL, Ronsky JR, Engsberg JR. Range of motion of the foot as a function of age. Foot & ankle. 1992;13(6):336-43.