Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 3 Issue 8 August 2020

Research Article

The Relationship between Foot Anthropometry and Vertical Jump Performance Using My Jump 2 App in Normal Population - A Cross Sectional Study

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DOI: 10.31080/ASOR.2020.03.0194

Received: June 04, 2020

Published: July 09, 2020

Abstract

Background: Vertical jump is a motor task which requires the interaction of nervous and musculoskeletal system. Variability in musculoskeletal structure has the potential to influence locomotor function. This study examined acute anthropometric measure in relation to vertical jump performance.

Purpose: The purpose of this study was to find the relation between foot anthropometry and vertical jump performance.

Procedure: The purpose and the procedure of the research were explained to the subjects and on the basis of inclusion and exclusion criteria, the subjects who were willing to participate in the research were selected. Total n=100 subjects were explained about how to perform vertical jump. After obtaining their anthropometric values, the subjects performed three trials of vertical jump and the average of performance parameters were recorded using ios based My Jump 2 app and was recorded as the final value.

Results: Data collected were entered and analyzed by SPSS version 16.0 for windows (IBM). Descriptive statistics was used to analyse baseline characteristics for all parameters of subjects. Mean score of all the parameters of subjects were taken and were analysed using Pearson's method of correlation. There is negative correlation between weight of the subject, jump height, foot length, toe length, heel length, navicular height and BMI. Positive correlation was found between vertical jump height and ROM of dorsi flexion and plantar flexion as well as calf girth.

Conclusion: There is correlation between different parameters of foot anthropometry and vertical jump performance in normal individuals.

Keywords: Foot Anthropometry; My Jump 2 App; Vertical Jump Performance; Foot Biomechanics

Abbreviations

VJP: Vertical Jump Power; VJH:Vertical Jump Height; VJF: Vertical Jump Force; VJFT: Vertical Jump Flight Time; VJS: Vertical Jump Speed;BMI:Body Mass Index; CMG: Calf Muscle Girth; HL: Heel Length; NH: Navicular Height; DF: Dorsi Flexion;PF: Plantar Flexion;TL: Toe Length;COM: Centre of Mass

Introduction

Body has 206 bones and each foot has 26 bones and 33 joints which makes almost one quarter of bones. Feet are the supportive foundation of the entire body as the entire body place an enormous burden up to them. As a supportive foundation of the entire body they get further weaken due to trauma [1].

The foot and ankle provides flexibility as well as stability due to presence of many bones, their shapes and their attachments. They work for the principle functions of propulsion and support. For propulsion they act like a flexible lever and for support they act like rigid structure that holds up the entire body. As a terminal part of the lowerkinetic chain the lower leg, ankle and foot have the ability to distribute and dissipate the different forces acting on the body through the contact with the ground [2,3].

The vertical jump is a movement when an athlete jumps vertically to achieve the highest point above the ground. The vertical jump is one of the most explosive physical movements executed in sports.It is one of the important tests to measure physical ability and potential performance of an individual. Vertical jump performance could serve for the assessment of muscle power, strength, muscle fibre composition, functional capacity and risk of falling as well. Vertical jump tests such as jump and reach, switch mat test, and belt test have been used to assess weightlifter, power lifter, football and basketball players, volleyball players, swimmers, dancers and college students. Vertical jump can also be used for rehabilitation [4,5].

Vertical jump performance can be affected by various anthropometric and biomechanical factors. Anthropometry consists of the measurement of body dimensions such as length, width and height. Foot dynamic anthropometry has a vital role in medical rehabilitation and sport science. It helps to improve well-being, health, comfort and safety. Foot anthropometry is very important for supporting feet structure. To predict the performance in running and jumping the measurement of lower limb specifically foot anthropometry is important in human being. Foot anthropometry includes foot length, toe length, navicular height and heel length. There are many studies available on foot anthropometry and its effects on different locomotion components. But there are very few studies which show the relation between different foot anthropometry and vertical jump performance [2,6].

The possibility of identifying the particular characteristics of normal individual with different training backgrounds using practical Vertical Jump measures may be relevant to specify the neuromechanical requirements of each activity, thus allowing them to enhance and individualise the strategies of training [7].

Different protocols are being used to analyse vertical jump performance. My jump 2 app is one among them. My jump 2 appwas developed by Carlos balsalobre.It is a mobile application used to measure vertical jump. It is one of the most reliable and valid iPhone apps. It is cheap, simple and very practical tool for evaluation of jumping ability. My jump 2 app is an easily usable application for assessing vertical jump height from flight time using the high-speed video recording facility on iPhone.In-app settings allow for slow motion playback for easy identification of the video frame in which jump take-off and landing can be analysed. My jump 2 app allows for a greater level of precision and accuracy in testing vertical jump, these measures also tend to be less expensive and more feasible [8].

Here, through this study we would like to put forward the relation between foot anthropometric values and vertical jump performance using the handy tool available, my jump 2 appin normal individuals of young age.

Statement of problem

Vertical jump can be affected by various factors, among them foot anthropometry plays a major role.As it can alter the biomechanics and in turn the load sharing process. Understanding the relationship between foot structure and motor functions has important implications. The relationship between foot anthropometry and various parameters of vertical jump are yet to establish in the available literature.

Aim of the Study

To evaluate the relationship between different foot anthropometry on vertical jump performance using My jump 2 app in normal individual.

Objectives of the Study

- To evaluate effect of Foot length, Toe length and Heel length on vertical jump performance.
- To evaluate effect of Ankle joint Mechanics/Ankle ROM on Vertical jump performance.
- To evaluate effect of Navicular height on Vertical jump performance.
- To evaluate the effect of calf muscle girth on vertical jump performance.

Study design

A cross sectional study.

Study population

Healthy young adult-age group (17-25 years).

Study duration

6 months.

Sampling method

Convenient sampling.

Sample size

N=100 subjects.

Inclusion criteria

- Young healthy individuals
- Age group 17 to 25 years
- Male and female both were included
- Paediatric and Geriatric subjects
- Subjects with bone or joint deformities
- Subjects with vertigo, balance problems and dizziness.

Materials

- A Measure tape for measuring Foot length, Heel length, Toe length, Navicular Height and girth measurement of calf muscle.
- Record sheet.
- Stadiometer for measuring height.
- Weighing machine for measuring weight.
- Goniometer for measuring Ankle ROM.
- Apple I pad 7th Generation with installed My jump 2 app.

Procedure

Participants were selected from S.S. Agrawal Institute of physiotherapy and medical care education. 100 students between the age group of 17-25 years took part in the study. On the basis of inclusion and exclusion criteria subjects were requested and who wanted to participate were selected. Written consent was taken from each participant. Procedure and purpose were explained.

After each subject signed the consent form, the height was measured by stadiometer in centimeters and Weight was measured by weighing machine in kilograms.

Foot anthropometry

The following measurement were recorded:

- **Foot length:**Using the measure tape the length of the foot is measured from longest toe to the back of the heel.
- **Toe length:**Using the measure tape measure the Distance of first metatarsal head to distal end of toe.
- **Heel length**
  - **Lateral heel length:**Using the measure tape measure the horizontal distance from lateral malleolus to the back of heel in sagittal plane.
  - **Medial heel length:**Using the measure tape measure the horizontal distance from
- **Navicular height:** Keep the subject in standing position and using a measure tape the height is measured from most prominent part of navicular to the ground.
- **Foot shape:** Shape of foot was observed with naked eyes and depending upon the type it was categorised into two groups:
  - **Egyptian foot:** In this type of feet, the first metatarsal is longer than second metatarsal. It is also called as Index plus type. The length of metatarsals progressively decreases.
  - **Greek foot:**In this type of feet the second metatarsal is longer than the first metatarsal.It is also called as Index minus or Morton's foot.
- **Girth measurement of calf:**Keep the Subject in sitting position, use a measure tape and measure at the level oflargest circumference of calf in centimetres.
- **Range of motion of ankle:** Make the subject sit in high sitting or sitting position; use a gonio-meter to assess Range of motion.

Dorsiflexion

- Centre the fulcrum over lateral malleolus
- Stable arm along the lateral midline of fibula
- Movable arm along the lateral aspect of fifth metatarsal.

Planterflexion

- Centre the fulcrum over medial malleolus
- Stable arm along the medial midline of tibia
- Movable arm along the medial aspect of first metatarsal.

Ask the subject to dorsiflex and planter flex the ankle to measure the range of motions.

My jump 2 app

It is an application available in app store of all apple devices through which the vertical jump can be measured.Subjects were explained about the app and a demo was given to the subjects about how to perform vertical jump. One subject was taken at a

time. The subjects were instructed to jump bare footed from the ground. Three trials of vertical jump were done by each subject and average of it was recorded. Tester was sitting in front of the subject holding an i pad parallel to the legs of the subject and recorded the vertical jump. Different parameters of the jumps were recorded using this app. Parameters such as vertical jump-height, power, speed, flight time, force were analysed and recorded from this app. Take-off and landing time were set by the tester after completion of one jump.

Vertical jump

The subjects were explained how to perform vertical jump. The jump was performed bare footed by subjects on the ground. While performing the jump the subjects were instructed to jump as high as possible without bending the knees.The jump was performed with free hands and adequate rest periods were given between three trials.

Results

Data collected were entered and analysed by SPSS (Statistical package for social science) version 16.0 for windows (IBM).

Descriptive statistics was used to analyse baseline characteristics for both the groups.

Results of the outcome measures were expressed as a summary measures (Mean ± SD) and presented with appropriate tables.

Pearson correlation method was used to analyse the effect of foot anthropometry on vertical jump.

p-value of < 0.05 was considered as statistically significant.

Shapiro-Wilk testwas performed to check the normality of data. The values were p <0.05 which indicates that the data follows normal distribution.

In the current study, total 100 subjects were included out of which 23 participants were males and 77 participants were females. The study participants were between the age group of 17-25 years.

There was difference in the variables mentioned above in both the male and female participants. The mean of dorsiflexion range, Heel length, Foot Length, Toe length and Navicular height were found to be more in male participants compared to female participants.

While, the mean value of plantar flexion range and calf muscle girth were found to be higher in females compared to males.

Out of 100 participants, 17 males and 58 females had Egyptian foot whereas 06 males and 19 females had Greek foot.

When different components of vertical jump were analysed, it shows the above mentioned findings. Females produced better jump height and power compared to males. (Maximum value of female's jump height and jump power > Maximum value of male's jump height and jump power).Females were found to have more jumping force compared to males while Males had better flight time compared to females. The maximum jump speed was same for both the genders, but the minimum jump speed was more in males than females.

Vertical jump height when correlated with weight (Þ= -0.258), Height (Þ= -0.162), BMI (Þ= -0.253),Heel Length (Þ= -0.304), Foot Length (Þ= -0.056), Toe Length (Þ= -0.089) and Navicular Height (Þ= -0.059); It showed negative correlation. Whereas, Dorsi-flexion Range (Þ= 0.207), Plantar Flexion Range (Þ= 0.023) and calf muscle girth (Þ= 0.035) had positive correlation with Vertical Jump Height.

Vertical jump power and force produced by males was negatively correlated with weight, height, BMI, Heel Length, Foot length, Toe length, Navicular Height. However, both were positively correlated with dorsiflexion range.The correlations between vertical jump power and plantar flexion range as well as calf muscle girth were 0 which indicates no relation between the two. Vertical jump force was found to have negative correlation with plantar flexion range (Þ = -0.026). All the correlations are statistically insignificant with p-value >0.05.

The speed of the vertical jump was negatively correlated with weight, height, BMI, Heel Length, Foot Length, Toe length, Navicular height and Calf muscle girth. It was positively correlated with dorsiflexion and plantarflexion range but the results were not significant statistically. Out of all, the correlation between heel lengths with vertical jump speed was significantly negatively correlated (p-Value ≤ 0.05).

Vertical jump height, power, force production, flight time and speed is significantly negatively correlated with BMI in females.

Vertical jump height is negatively correlated with Weight, heel length, foot length and toe length while height, dorsiflexion and plantar flexion ranges, Navicular height and calf muscle girth are positively correlated but it was statistically insignificant.

Vertical jump power was positively correlated with height, dorsiflexion and plantar flexion ranges, navicular height and foot length which were statistically insignificant. Negative correlation was found with heel length, toe length and calf muscle girth.

However, participant's height, dorsiflexion and plantarflexion ranges, foot length, navicular height and calf muscle girth were positively correlated with vertical jump flight time but it was statistically insignificant. Negative correlation was found between vertical jump flight time and weight, heel length, toe length which was not significant.

Out of all the variables weight, heel length and toe length were negatively correlated with vertical jump force and speed. Calf muscle girth was again negatively correlated with speed but it was positively correlated with force production. Other than that all factors were positively correlated with both the components of vertical jump.

However,all of these correlations were statistically insignificant except its correlation with BMI as mentioned above.

Figure 1: Foot length.

Figure 2: Toe length.

Figure 3: Medial heel length.

Figure 4: Lateral heel length.

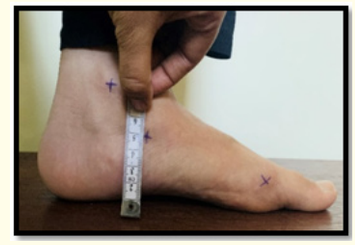


Figure 5: Navicular Height.

Figure 6: Calf muscle girth.

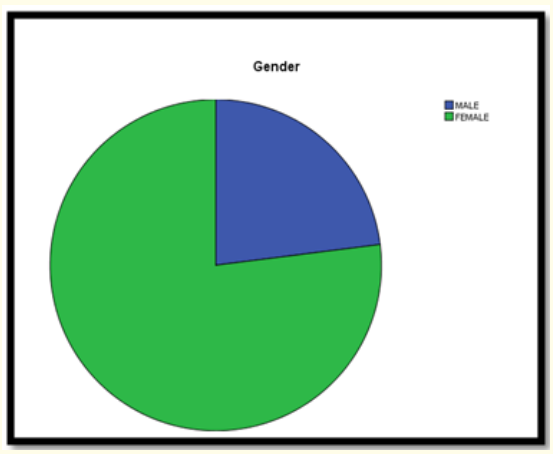
Figure 7: Dorsiflexion ROM of ankle.

Figure 10: Take off phase.

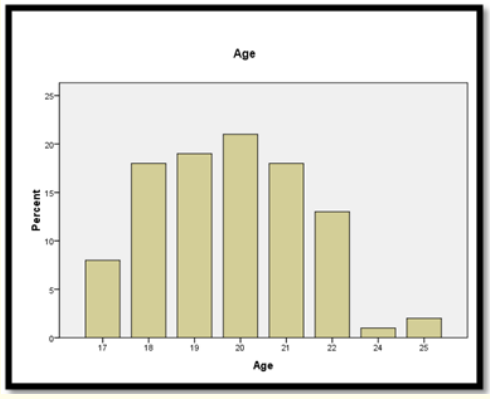
Figure 8: Plantarflexion ROM of ankle.

Figure 11: Landing phase.

Figure 9: Starting squat position.



Graph 1: Gender wise distribution of participants.



Graph 2: Age wise distribution of participants.

Variables	Mean ± SD
Weight	54.69 ± 13.73
Height	162.79 ± 8.28
BMI	20.63 ± 4.33

Table 1: Descriptive statistics of participants' variables.

Variables	Mean ± SD Male	Mean ± SD Female
Dorsiflexion	19.58 ± 4.41	19.23 ± 4.90
Planter flexion	44.44 ± 4.48	44.56 ± 6.51
Heel length	6.19 ± 0.6438	5.86 ± 0.51
Foot length	25.78 ± 1.19	23.35 ± 1.24
Toe length	7.28 ± 0.72	6.66 ± 0.77
Navicular height	4.74 ± 0.61	4.16 ± 0.54
Calf muscle girth	2.91 ± 0.42	2.96 ± 0.498

Table 2: Anthropometric values of male and female participants.

Shape of foot	Male	Female
Egyptian foot	17	58
Greek foot	06	19

Table 3: The frequency of different shapes of foot in both the groups.

Vertical jump components	Male		Female	
	Minimum	Maximum	Minimum	Maximum
Jump height	6.10	21.20	3.90	25.20
Jump power	1095	5494	679	6605
Jump flight time	223	1050	178	433
Jump force	1993	5253	1524	5867
Jump speed	0.6	1.0	0.4	1.0

Table 4: Vertical jump component values for male and females.

		Weight	Height	BMI	DF	PF	HL	FL	TL	NH	CMG
VJH	Þ	-0.258	-0.162	-0.253	0.207	0.023	-0.304	-0.056	-0.089	-0.059	0.035
	P-value	0.234	0.46	0.245	0.344	0.919	0.158	0.8	0.687	0.789	0.874
VJP	Þ	-0.248	-0.22	-0.224	0.143	0	-0.33	-0.096	-0.137	-0.043	0
	P-value	0.254	0.313	0.305	0.516	0.998	0.124	0.662	0.533	0.845	0.998
VJFT	Þ	-0.037	-0.047	-0.028	0.07	0261	0.015	-0.147	-0.108	-0.003	0.048
	P-value	0.868	0.832	0.899	0.752	0.228	0.947	0.504	0.625	0.989	0.829
VJF	Þ	-0.224	-0.222	-0.193	0.109	-0.026	-0.234	-0.036	-0.123	-0.102	0.09
	P-value	0.304	0.309	0.379	0.621	0.908	0.283	0.871	0.575	0.643	0.683

Table 5: Correlation between anthropometric variables and vertical jump components in Males.

*Significance level p ≤ 0.05 is considered to be statistically significant (þ = pearson's correlation coefficient).

		Weight	Height	BMI	DF	PF	HL	FL	TL	NH	CMG
VJH	Þ	-0.204	0.159	-0.338	0.096	0.091	-0.165	-0.002	-0.136	0.095	0.029
	p-value	0.075	0.168	0.003*	0.408	0.432	0.151	0.988	0.239	0.41	0.803
VJP	Þ	-0.222	0.092	-0.335	0.103	0.062	-0.144	0.041	-0.042	0.104	-0.023
	p-value	0.052*	0.425	0.003*	0.371	0.591	0.21	0.724	0.714	0.367	0.842
VJFT	Þ	-0.167	0.203	-0.318	0.084	0.044	-0.147	0.071	-0.055	0.124	0.049
	p-value	0.147	0.077	0.005*	0.466	0.706	0.202	0.601	0.944	0.282	0.675
VJF	Þ	-0.208	0.149	-0.346	0.11	0.071	-0.136	0.055	-0.05	0.124	0.021
	p-value	0.069	0.196	0.002*	0.339	0.542	0.237	0.637	0.667	0.284	0.854
VJS	Þ	-0.19	0.206	-0.334	0.106	0.078	-0.138	0.061	-0.008	0.156	-0.114
	p-value	0.097	0.073	0.003*	0.361	0.5	0.233	0.601	0.944	0.174	0.323

Table 6: Correlation between anthropometric variables and vertical jump components in females.

*Significance level $p \leq 0.05$ is considered to be statistically significant. (Þ= Pearson's correlation coefficient).

Discussion

The Primary aim of the study was to Find Relationship between Foot anthropometry and Vertical jump by using My Jump2 app in normal population. Total of 100 Subjects were included with age group between 17 to 25 years. Among them Egyptian foot was more common compared to Greek foot. Foot Anthropometry of all the subjects was taken. The Subjects were made to Perform Vertical jump and were assessed using my jump 2 app. Correlations between different foot anthropometries and vertical jump parameters were noted. In our study there is negative correlation between weight of the subject, jump height and foot length, toe length, heel length, Navicular Height, BMI and Positive correlation between vertical jump height and ROM of Dorsiflexion, Plantarflexion, Calf girth.

In this study Vertical jump was analysed using My jump 2 app; various components of Vertical jump such as height, power, flight time, speed and force were analysed. We hypothesized that foot anthropometry will affect vertical jump. This hypothesis was supported as in our study foot anthropometry was affecting various component of vertical jump.

In present study, we found that males have better jump height compared to females though the maximum height of jump achieved during study was by a female participant, overall height of the jump was better in males compared to females. The minimum jump height of males on average was 6.10 while in females it was 3.90. This result is supported by the result of previous study wherein male players jumped higher than females. Because in Indian young national players more strength and less body fat were seen in males and male players were taller than females [9]. Subjects who have participated in sports involving jumping their entire lives predispose to jump higher. Other subjects who were not involved in activities which require jump may not be comfortable in the task so in them vertical jump height can be lesser.

We hypothesized that subject's height and vertical jump performance are correlated. Subjects with taller height were able to produce more anaerobic power which leads to increase vertical jump performance. However, it depends upon individual power producing capacity [10]. We found these factors to be correlated in our study. Further research should be done to investigate the possible cause between them.

In our study jump speed was same in both genders and minimum jump speed is seen in male subject. This could be because vertical jump is a very quick movement. Most vertical jump happened in around 2 seconds which was very quick velocity for subjects to display their strength. When the gravitational force exceed than the force produce by the subject during vertical jump it pulls the subject towards the ground so the jump remains only for a fraction of second which is less time to notice the change [11].

Individual with a greater dorsiflexion ROM were reported to have the ability to place their heels in contact to the ground during

squat, which causes the ankle planter flexor muscles to achieve sufficient force generating capacity for a deeper squat position before take-off.It has been shown that an active muscle, when lengthened, may sustain high forces and stretch the tendon sufficiently so that it can store elastic energy for the late concentric phase when the activity starts to decay. Thus, dorsiflexion ROM is a contributor to achieve sufficient force generating capacity and proper vertical shift of COM during vertical jump performance.Our study shows that dorsiflexion ROM have impact on vertical jump performance. Subjects who were having greater dorsiflexion ROM can perform better vertical jump [12-14].

Shorter moment arm is more beneficial for force production. In our study there is a positive correlation found between plantarflexion and vertical jump performance. This can be due to shorter moment arm which enhances the force production while performing the plantarflexion. Due to Shorter moment arm larger joint moment develops so larger joint power output and work output can be obtained. Thus, this results in larger muscle force development which leads to higher vertical jump [15].

Vertical jump is affected by various physiological and biomechanical parameters. Vertical jump is determined through vertical velocity component and gravity during takeoff phase. Jumping process requires an external force as ground reaction force which is the result of generated torque transmitted to the ground. Joint torque is generated from muscle contraction during structure displacement. Final torque in a joint is difference of contractile forces in agonist and antagonist muscles [16].

Moreover, the amount of forces depends on muscle properties. Ground reaction forces should be greater than weight. It will be transmitted to the body and determine velocity of center of mass. An appropriate vertical jump could be explained through Newton's second law directed dependence of body acceleration with mass and third law action and reaction law [17].

There are other reasons like foot deformities such as Flat foot which is determine by the navicular height. Subjects with flatfoot have a significantly larger peak pressure in the region of hallux and larger contact area of center forefoot than that of normal foot group, and larger contact area in medial midfoot.it can be concluded that people with flat arched feet may have a poorer ability of self-regulation when facing a movement with rapid impact force like vertical jump, which will increase the risk of injuries [18].

Smaller anthropometric measurement will produce higher jump. Smaller toes, feet and lesser weight produce higher jump according to size principle. Individual anthropometric differences may affect the jump performance. Individual experiences with jumping may affect jump performance. This could be the reasonin our study that there is a negative correlation between anthropometric measurements and vertical jump performance [19].

In our study there is a negative correlation between heel length and vertical jump performance. Smaller heel length reduces the speed of shortening of the muscles and allows the muscles to produce forces higher than those that would be generated with a longer heel, due to force velocity effects.This could the reason for the negative correlation in our study [20].

We hypothesized that a longer toe will produce greater vertical jump. During take of the longer toes stay in contact with the ground for a longer duration, this allows for a greater force production and creates great acceleration due to ground reaction forces [21]. However, in our study we couldn't find a positive correlation between them. Future research should investigate the possible relationship between toe length and time of vertical impulse generation during jumping.

Gender effect certainly plays a significant role on the vertical jump. In this study weight is negatively correlated with vertical jump performance in both genders. Weight is related to the work performed during vertical jump. Since work is the product of average force acting on the subject and displacement of jump, heavier athletes need more work to move the body to same displacement achieved by lighter athletes [22].

Also there is a negative correlation between BMI and all components of vertical jump. As more weight leads to decrease in the jump height and other components of vertical jump like flight time gets decreased due to gravity. According to newton's second law as mass and acceleration are negatively correlated so, more the subject's weight lesser the vertical jump performance [17].

In our study there is no correlation was found between planter flexion and calf muscle girth with vertical jump power. As power is the ability to work or generate energy which doesn't depend upon mass. As Vertical jump is performed from squat position so planter flexion doesn't produce the torque hence there is no correlation found between planter flexion and vertical jump power in this

study. A study shows that greater calf circumference has significant correlation with vertical jump height and muscle size affects the force producing ability and jump performance. Perhaps, a greater physiological cross section of muscles contains more sarcomeres contributing in muscular contractile property which leads to more cross bridge formation and a finally greater force production [23].

A study on relationship between calf muscle girth and vertical jump ability found that there is positive correlation between calf muscle girth and vertical jump height in female subjects which were elite population. In our study there is positive correlation between calf muscle girth and vertical jump height in male and female both non elite populations [24-26].

The two main factors that affect performance of different subjects are their lack of skill or coordination and their inability to perform at their best level at any given time.

Limitation of the Study

- The study was bounded to asymptomatic healthy young adults within age group 17 - 25 years so, results cannot be generalised to geriatric and paediatric populations.
- The foot examination and categorisation was done by observation individually.
- All the different types of foot population were not included in study.
- Study was focused on only one type of vertical jump.

Future Implications

- The comparative study can be done on elite and non-elite population using same methodology.
- Study can be done in different age group for generalizing the result to the maximum population.
- A study can be done using vertical jump analyzer in different types of foot.
- A study can be done involving multiple joint and limb length.
- A study can be done on different foot deformities and its relation with vertical jump.

Clinical Implications

Along with other factors affecting Vertical jump performance, measurements of foot anthropometry can be considered as one of the factor contributing to the performance of Vertical jump.

Conclusion

There is a correlation between different parameters of foot anthropometry and vertical jump performance in normal individual.

Conflict of Interest

We declare that there was no funding received and there was no conflict of interest during this study duration.

Acknowledgement

We are thankful to our department staffs at S.S. Agrawal Institute of Physiotherapy and medical care education for their continuous co-operation during this study.

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