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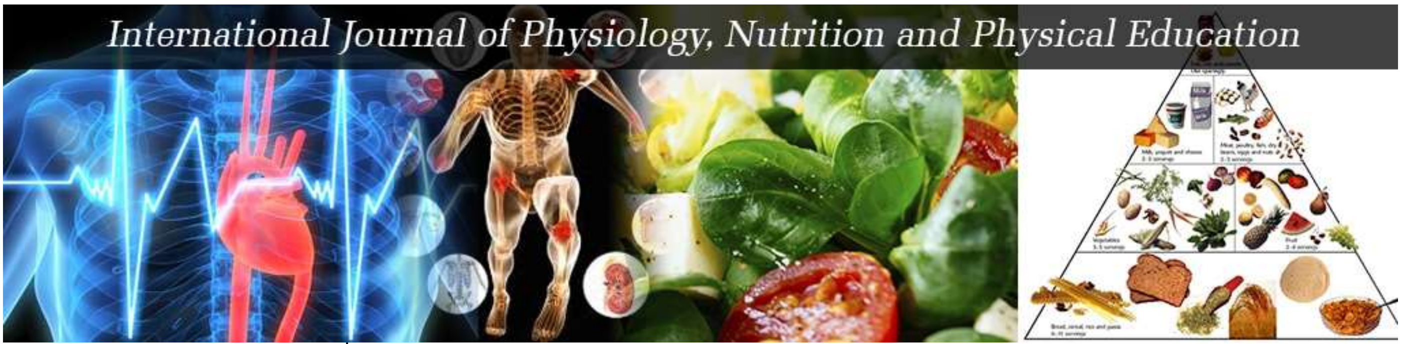

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Relationship between quadriceps muscle fiber architecture and lunges performance

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Abstract
The purpose of this research was to ascertain the relationship between the architectures of the lower body muscles and lunges performance. Thirty recreationally active, untrained males (mean age: 17±1.25 years) were recruited and participated in two testing sessions: anthropometrics and muscle architecture, and one-repetition maximum (RM) lunges test. B-mode ultrasonography was used to assess muscle thickness, pennation angle, and fascicle length in the vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF). The 1RM lunges performance was estimated using multiple-RM lunges testing. The relationship between lower body muscle architectures and lunges performance was studied using correlation analysis. Overall, lunges performance was positively correlated with muscle thickness and fascicle length of all muscles. Pennation angle, on the other hand, was shown to be inversely associated to lunges performance. The results of this research suggested that having a thicker, longer fascicle length, and a lower pennation angle of the lower body quadriceps muscle is important for improving lunges performance, which is one of the most specific motions in lower body strength development and enhanced performance.

Keywords: Muscle architecture, vastus laterialis, pennation angle, fascicle length, muscle thickness, ultrasound

Introduction

To put it simply, the quadriceps is activated whenever you straighten a bent knee. They help you with tasks that you perform on a regular basis, such getting out of a chair, walking, climbing stairs, and lungesting. You extend your knee whenever you kick a ball, run, stand up, or do any other action that needs you to straighten your legs at the knee joint. When moving downhill, whether by jogging or walking, the quadriceps are significantly activated. They are used in activities including cycling, football, handball, and basketball, among others.

The quadriceps femoris is the largest muscle in the human body. The lower leg contains the quadriceps femoris, a hip flexor and knee extensor. It is composed of four distinct muscles: one rectus femoris and three vastus muscles (hamstring muscle). They make up the bulk of the thigh's mass and are one of the strongest muscles in the body as a whole. The quadriceps femoris is situated in the anterior thigh compartment. Rectus Femoris, Vastus Medialis, Vastus Lateralis, and Vastus Intermedius are the four muscles that make up the quadriceps group. (Lucinda Hampton, 2021) [15]. Muscle architecture was originally defined by Gans and De Vries. The macroscopic arrangement of muscle fibres that regulates a muscle's mechanical function is referred as the muscle architecture. Ref. Fig. No 1 Muscle architecture parameters include physiological cross-sectional area (PCSA), Pennation angle (PA), Fiber Length/ Fascicle Length (FL), and Muscle Thickness (MT). (Salimin, 2018) [20]**.**

Muscle Architectural Parameters

Physiological cross-sectional area is the area of the cross section of a muscle perpendicular to its fibers, generally at its largest point. (Brughelli *et al*., 2010) [6] Pennation angle is defined as the angle between a fascicle's orientation and the tendon axis. (Salimin, 2018) [20] Muscle fiber length is defined as the distance from the origin of the most proximal muscle fibers to the insertion of the most distal muscle fibers.(Kumagai *et al*., 2000) [14] Muscle thickness is defined as the thickness between two fascia of muscle. In general thickness considered as the main factor for determining muscle size. (Abe *et al*., 2001) [2]

Scientific works on muscular architecture are presently trending in this time. Various architectural variables and their relationship with sports are briefly explained.

Muscle force is directly related to physiological cross-sectional area. Muscle velocity is inversely related to the length of the muscle fibers. Sprinters have longer fascicles than distance runners, and this is reflected in their leg muscle length. Sprinters' leg muscles have a longer fascicle length (vastus lateralis) and a smaller pennation angle than the general population. Greater pennation angle permits a greater quantity of contractile tissue to bind to a given piece of tendon, or aponeurosis, thus increasing the physiological cross-sectional area of a muscle. (Blazevich AJ, Coleman DR, Horne S, 2009; K Albracht, A Arampatzis, 2008; MM Bamman, B R Newcomer, D E Larson-Meyer, R L Weinsier, 2000) [5, 13, 16] The increment in pennation angle will causes a cross sectional area of muscle to have more number of fibers. This will therefore boost the muscular ability to produce more force. (Manal K, Roberts DP, 2006) [17] discovered pennation angle to be linked with muscle thickness and improvement in strength. However, a increment of pennation angle with constant cross-sectional area has been reported to cause reduction of strength (Ikegawa S, Funato K, Tsunoda N, Kanehisa H, 2008) [12]. This condition was assumed to be influenced by the angle of pull of the fibers that is indirect to the draw of the muscle in total, and thus cause the pull of the muscle in total lowered by the cosine of the pennation angle. Fascicle length is the distance of fascicle from aponeurosis to another aponeurosis. Mathematically, it is a product of fascicle thickness and pennation angle. Fascicle length will be increased with the increment of muscle thickness and decrement of pennation angle. A difference in muscle thickness in the leg muscles (vastus lateralis, gastrocnemius medials and lateralis) is a significant element in distinguishing sprinters from long distance runners (Salimin, 2018) [20].

Muscle architecture has been correlated to running, lungesting, lunging and jumping ability in a variety of earlier studies. (Abe *et al*., 2001; Kumagai *et al*., 2000; Salimin, 2018) [2, 14, 20] The lunges has been shown to activate thigh muscles especially quadriceps. Lunges s are usually performed on a lever machine. The rectus femoris and vastus muscles in the front of the thigh are primarily targeted by this exercise. Lunges is a strength training exercise that is used to improve lower body strength, vertical jump and muscle definition. Lunges improves lunges technique by strengthening and stabilising the quadriceps muscle and knee.

. In technical terms, lunges is "closed chain kinetic" exercise, as opposed to a "open chain kinetic" exercise like leg extension. The difference is that in the lunges, the body part you're working on is anchored (feet on the ground), whereas in the leg extension, you're moving the padded bar, which means your legs aren't stationary as you work, and thus the chain of movement is open. (Bączkowicz D, Kręcisz K, 2019) [3]. The concept of specificity in training has received considerable mention and attention over the past decade. (Fleck, S. J., & Kraemer, 2014) [9] Most movements in sports involve an athlete jumping in air vertically or horizontally and executing skills. To better train the body to become functional in various directions, lunge extension is suggested to be included in the training program. (Sale, 1988; Tippett, S. R., 1995) [19].

This study examines the relationship between lunges performance of dominating leg and muscle fiber, muscle thickness, fascicle length and pennation angle of dominating leg vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF).

Material and Methods

Selection of Subject

In this work of investigation a total sample comprised of 30 untrained male studying in schools of Gwalior, Madhya Pradesh was considered as sample for present investigation. Purposive sampling technique was employed for selecting sample. The selected subjects' age ranged between 13 to 19 years. Required data was collected after taking consent of concerned subject and parents of selected subject.

1 RM Lunges Test

The participants were instructed to stand with their hands holding a barbell placed on their shoulders, with their feet shoulder width apart. They lunged forward with their dominant foot and lowered the thigh until parallel with the ground, and then returned back to the starting position. They were required to take a big step forward during downward position, with the leading knee not extended beyond the toes of the same leg. The non-dominant foot was not to move from its starting position, and the head had to face forward for neutral neck position. (Baechle TR, 2008; Haff, Greg, Triplett, 2016; Nadzalan *et al*., 2018) [4, 10, 22].

The multiple-RM testing protocol were conducted for the 1RM lunges performances following the guidelines by the National Strength Conditioning Association. (Baechle TR, 2008) [4] During the test, participants were instructed to warm up with a light resistance that easily allows 5 to 10 repetitions. Next, participants were provided with a 1-minute rest period. Participants were required to lift a load that he estimated can perform 8RM. If the participants were able to lift more than 8RM, the load was increased 10% to 20% of that load. The load was continuously changed if the participants can complete more than 8RM with proper exercise technique. Three trials were given for each participant to obtain the 8RM score. Failure were defined as the time point when the participant paused more than 1s when the leg was in the extended position, or if the participant was unable to complete each repetition in a full range of motion. (Clark M, Lucett S, McGill E, 2018; Haff, Greg, Triplett, 2016; Nadzalan *et al*., 2018) [7, 10, 22] The one repetitive maximum was noted down by the assistant as maximum strength score.

Determination of Muscle Architectural Parameters

Before collecting ultrasound images, participants reported to the laboratory and laid supine for 15 minutes to allow fluid shifts to occur. Following that, non-invasive skeletal muscle ultrasound images using B-Mode ultra sonography (Wipro Ge Voluson E) of the quadriceps muscles were obtained. To improve spatial resolution, a 12 MHz linear probe scanning head was coated with water soluble transmission gel and positioned on the skin's surface to create acoustic contact without disturbing the dermal layer to gather the image. All measurements were collected on the dominant leg by the same technician. For each muscle in all individuals, the anatomical position for all ultrasound measurements was standardized. Breifly, Pennation angle (PA) was defined as the angle at which muscle fibre fascicles inserted into the deep aponeurosis. The length of the fascicular path (FL) between the insertions into the superficial and deep aponeurosis was quantified, and the missing component of the fascicle was calculated by extrapolating linearly the fascicular path and the aponeurosis where the fascicular path went beyond the obtained picture. Muscle thickness (MT) was determined by measuring the distance between the subcutaneous adipose tissue and the intermuscular contact. The average of three successive frames was calculated. Repeated scanning of muscle thickness, pennation angle, and fascicle length (Ref. Fig No. 1) measurements yielded intraclass correlation values varying from 0.9 to 0.996 ($p<0.001$). (Nadzalan *et al*., 2017) [18].

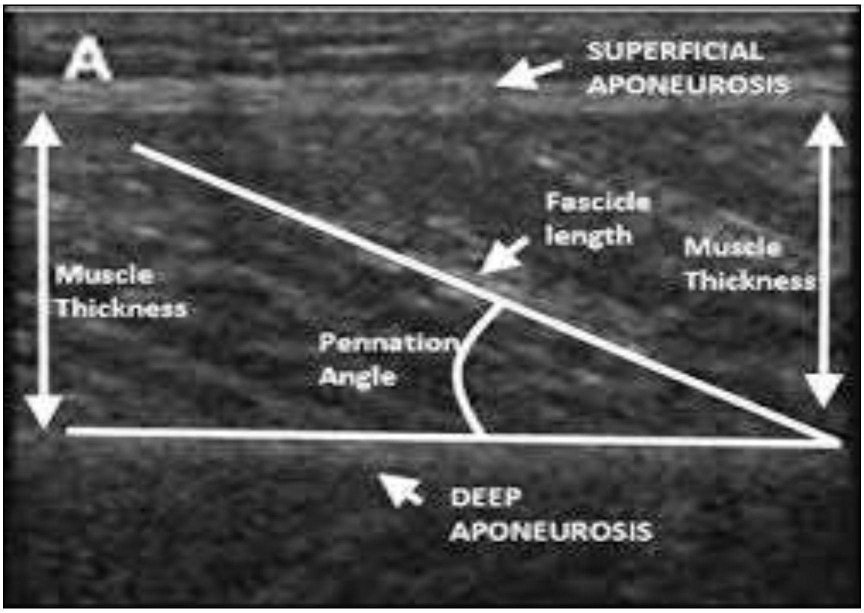

Fig 1: Vastus Lateralis muscle architectural parameters.

Muscle	Measurement Site
VL	Midpoint of total length between the greater trochanter and lateral epicondyle of femur on the line parallel to the RF line passing through the lateral border of patella
VM	Midpoint of total length between the greater trochanter and lateral epicondyle of femur on the line parallel to the RF line passing through the medial condyle of femur
RF	Midpoint of total length between greater trochanter and lateral epicondyle of femur on the line connecting the anterior superior iliac spine and center of patella

Statistical analysis

Pearson Correlation was performed to determine the relationship between muscle architecture of dominating leg and the 1RM dominating lunges performance. Statistical significance was considered at an α-level of $p<0.05$. The statistical analyses were performed using SPSS version 20. In addition, magnitude of effect for the correlations was based on the following scale: trivial <0.10; small 0.10-0.29; moderate <0.30-0.49; large <0.50-0.69; very large <0.70-0.89; and nearly perfect >0.9. (Hopkins, 2000) [11].

Results

Table 1: Descriptive statistics of physical characteristics of selected subjects.

Age (years)	Body Mass (kilogram)	Height (cm)
17±1.25	66±5.75	171.7±6.20

Table 2: Descriptive statistics of RF, VL, VM muscle architecture of selected subjects.

Muscle	Muscle Architecture	Mean	Std. Dev.
Rectus Femoris	Pennation Angle(^{0})	12.35	1.27
	Fascicle Length(cm)	8.50	0.77
	Muscle Thickness(cm)	1.72	0.90
Vastus Lateralis	Pennation Angle(^{0})	17.42	1.44
	Fascicle Length(cm)	8.66	0.74
	Muscle Thickness(cm)	2.34	0.06
Vastus Medialis	Pennation Angle(^{0})	16.78	0.95
	Fascicle Length(cm)	8.98	0.70
	Muscle Thickness(cm)	2.62	0.07

Table 3: Descriptive statistics of 1 RM Lunges score of selected subjects.

	Minimum	Maximum	Mean	Std. Dev.
1 RM Lunges Score (kg)	30	53	43.16	6.75

Table 4: Correlation analysis of RF, VL, VM muscle architectures and 1RM lunges

Muscle	Muscle Architecture	1 RM Lunges
Rectus Femoris	Pennation Angle	-0.69*
	Fascicle Length	0.67*
	Muscle Thickness	0.61*
Vastus Lateralis	Pennation Angle	-0.74*
	Fascicle Length	0.701*
	Muscle Thickness	0.69*
Vastus Medialis	Pennation Angle	-0.57
	Fascicle Length	0.51
	Muscle Thickness	0.49

Table No. 1 depicts the descriptive statistics of the research participants' age, weight, and height. The selected subject's age mean and standard deviation were 17 and 1.25, respectively. The selected subject's body mass mean was 66 kg, and the standard deviation was 5.75 kg. The selected subject's mean height was 171 cm, and the standard deviation was 6.20 cm.

The descriptive statistics of muscle architecture, including the Pennation Angle, Fascicle Length, and Muscle Thickness of the Rectus Femoris (RF), Vastus Lateralis (VL), and Vastus Medialis (VM), are shown in Table No. 2. The mean and standard deviation of pennation angle for Rectus Femoris

(RF), Vastus Lateralis (VL), and Vastus Medialis (VM) were 12.35±1.27, 17.42±1.44, and 16.78±0.95, respectively. The mean and standard deviation of fascicle length for RF, VL, and VM were 8.50±0.77, 8.66±0.74, and 8.98±0.70, respectively. The mean and standard deviation of muscle thickness for RF, VL, and VM were 1.72±0.90, 2.34±0.06, and 2.62±0.07, respectively. Table No. 3 illustrates descriptive data for 1RM single lunges performance. The 1 RM single lunges test had a mean and standard deviation of 43.16 and 6.75 respectively.

The correlation analysis between muscle architecture and 1RM score is shown in Table 4. There was a significant negative correlation between 1RM and the pennation angle of RF, VL and VM ($p<0.05$). There was a significant positive correlation between 1RM and the fascicle length of RF, VL and VM ($p<0.05$). There was a significant positive correlation between 1RM and muscle thickness of RF, VL and VM ($p<0.05$).

Discussion on Findings

This study has shown that there are relationships between the RF, VL and VM muscle architectures and lunges performance. Fascicle Length and Muscle Thickness were shown to be positively correlated with lunges performance. However, Pennation Angle was found to be negatively correlates performance of lunges. The increment in pennation angle will causes a cross sectional area of muscle to have more number of fibers. This will therefore boost the muscular ability to produce more force. (Manal K, Roberts DP, 2006) [17] discovered pennation angle to be linked with muscle thickness and improvement in strength. However, a increment of pennation angle with constant cross-sectional area has been reported to cause reduction of strength (Ikegawa S, Funato K, Tsunoda N, Kanehisa H, 2008) [12]. This condition was assumed to be influenced by the angle of pull of the fibers that is indirect to the draw of the muscle in total, and thus cause the pull of the muscle in total lowered by the cosine of the pennation angle. As a result, this research found a negative connection between pennation angle and 1 RM lunges performance, indicating that strength increases as pennation angle decreases.

Fascicle length is the distance of fascicle from aponeurosis to another aponeurosis. Mathematically, it is a product of fascicle thickness and pennation angle. Fascicle length will be increased with the increment of muscle thickness and decrement of pennation angle. (Salimin, 2018) [20] reported a difference in muscle thickness in the leg muscles (vastus lateralis, gastrocnemius medials and lateralis) is a significant element in distinguishing sprinters from long distance runners. As a result, this research revealed a positive correlation between 1 RM lunges performance and fascicle length, as well as a positive correlation between 1 RM lunges performance and muscle thickness.

(Earp, Jacob E; Kraemer, William J; Newton, Robert U; Comstock, Brett A; Fragala, 2014) [8] in contrast to (Abe, T., Kumagai, K. & Brechue, 2000; Kumagai *et al*., 2000) [1, 14] investigations, observed that greater muscle thickness and pennation, as well as shorter fascicles, were favourable for leaping ability at higher pre-stretch loads. These findings revealed that more pennation and shorter fascicles were linked to improved leaping performance at higher pre-stretch loads, highlighting the importance of training specialisation.

According to (Earp, Jacob E; Kraemer, William J; Newton, Robert U; Comstock, Brett A; Fragala, 2014; Nadzalan *et al*., 2017) [8, 18] lunge performance improved with larger muscle thickness and pennation angle when determined by 1RM score. These disparate results showed that muscle architecture varies depending on the individual's training and the exercise or skill performed.

Conclusion

Overall, relationships existed between muscle architecture and 1RM lunges performance. Findings suggested the significance for having thicker, longer fascicle length and less pennation angle of lower body muscle in boosting lunges performances. Training might be structured to produce specific changes in muscle architecture to allow for greater performance in this movement which is one of the most performed movements in sport.

References

1. Abe T, Kumagai K, Brechue WF. Fascicle length of leg muscles is greater in sprinters than distance runners. Med. Sci. Sports Exerc. 2000;32(6):1125-1129.
2. Abe T, Fukashiro S, Harada Y, Kawamoto K. Relationship between sprint performance and muscle fascicle length in female sprinters. Journal of Physiological Anthropology and Applied Human Science. 2001;20(2):141-147. https://doi.org/10.2114/jpa.20.141
3. Bączkowicz D, Kręcisz K, Borysiuk Z. Analysis of patellofemoral arthrokinematic motion quality in open and closed kinetic chains using vibroarthrography. BMC Musculoskelet Disord. (Doi:10.1186/S12891-019-2429-Z). 2019;20(1):48.
4. Baechle TR, Earle RW. Essentials of strength training and conditioning. Champaign. Human Kinetics; c2008.
5. Blazevich AJ, Coleman DR, Horne S, Cannavan D. Anatomical predictors of maximum isometric and concentric knee extensor moment. European Journal of Applied Physiology. 2009;105(6):869–878.
6. Brughelli M, Cronin J, Nosaka K. Muscle architecture and optimum angle of the knee flexors and extensors: Acomparison between cyclists and Australian rules football players. Journal of Strength and Conditioning Research. 2010;24(3):717–721. https://doi.org/10.1519/JSC.0b013e318197009a
7. Clark M, Lucett S, McGill E, MI, SB. NASM Essentials of Personal Fitness Training; c2018.
8. Earp Jacob E, Kraemer William J, Newton Robert U, Comstock Brett A, Fragala M. Lower-Body Muscle Structure and Its Role in Jump Performance During Lunges, Countermovement, and Depth Drop Jumps. Journal of Strength and Conditioning Research. 2014;24(3):722–729.
9. Fleck SJ, Kraemer W. Designing Resistance Training Programs. Human Kinetics; c2014.
10. Haff Greg, Triplett NT. Essentials of strength training and conditioning; c2016.
11. Hopkins WG. Measures of reliability in sports medicine and science. Sports Med. 2000;30(1):1-15.
12. Ikegawa S, Funato K, Tsunoda N, Kanehisa H, Fukunaga T, Kawakami Y. Muscle force per cross-sectional area is inversely related with pennation angle in strength trained athletes. Journal of Strength and Conditioning Research. 2008;22(1):128-131.
13. Albracht K, Arampatzis A, Baltzopoulos V. Assessment of muscle volume and physiological cross-sectional area of the human triceps surae muscle *in vivo*. Journal of Biomechanics. 2008;41(10):2211-2218.

14. Kumagai K, Abe T, Brechue WF, Ryushi T, Takano S, Mizuno M. Sprint performance is related to muscle fascicle length in male 100-m sprinters. Journal of Applied Physiology. 2000;88(3):811–816. https://doi.org/10.1152/jappl.2000.88.3.811
15. Lucinda Hampton. Quadriceps Muscle; c2021. Https://Www.Physio-Pedia.Com/Quadriceps_Muscle.
16. Bamman MM, Newcomer BR, Larson-Meyer DE, Weinsier RL, Hunter GR. Evaluation of the strength-size relationship *in vivo* using various muscle size indices. Med Sci Sports Exerc. 2000;32(7):1307-1313.
17. Manal K, Roberts DP, Buchanan TS. Optimal pennation angle of the primary ankle plantar and dorsiflexors: variations with sex, contraction intensity, and limb. Journal of Applied Biomechanics. 2006;22(4):255-263.
18. Nadzalan AM, Mohamad NI, Low J, Lee F, Chinnasee C. Relationship between lower body muscle architecture and lunges performance. Journal of Sports Science and Physical Education; c2017. http://jsspj.upsi.edu.my/
19. Sale DG. Neural adaptation to resistance training. Medicine and Science in Sports and Exercise. 1988;20(5 suppl):135-145.
20. Salimin N. Muscle Architecture and Exercise Performance: A Mini Review. Biomedical Journal of Scientific & Technical Research. 2018;3(5):5-7. https://doi.org/10.26717/bjstr.2018.03.000958
21. Tippett SR, Voight ML. Functional progressions for sport rehabilitation. Human Kinetics; c1995.
22. Nadzalan AM, Mohamad NI, Lee JL, Chinnasee C. Relationship between muscle architecture and badminton-specific physical abilities. Human Movement. 2018;19(1):44-50.