Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 11, Issue 04, November 2020: 2510-2517
DOI: 10.53555/tojqi.v11i4.10170

Research Article

Lunges Performance Predicted By Multiple LinearRegression Model With Muscle Architectural Parameters

Ajay Kumar[1*], Dr. Briender Jhajharia[2]

Abstract

Purpose: - The primary objective of this research was to predict using a multivariate regression equation using muscle architecture parameters.

Materials and methods. The study sample consisted of 30 recreationally active male students from Gwalior, Madhya Pradesh. One repetition maximum multiple lunges test was used to determine maximum strength. Muscle architectural parameters (Vastus Laterialis, Pennation Angle, Fascicle Length, and Muscle Thickness) were measured using B-mode ultrasonography.

Results. The selected muscle architectural parameters i.e. Fascicle Length, Muscle Thickness and Pennation Angle of vastus laterialis, t-values were 3.485, -2.577 and -4.256 respectively. For all the three regression coefficients are significant as their significance values (p values) are less than *05.* Lunge performance was predicted by a multivariate regression equation using vastus lateralis muscle architectural parameters.

Conclusions. The developed regression equation for predicting lunges performance was **Y2** = 104.371 + 3.464 (VL_FL) -7.959 (VL_MT)-2.678 (VL_PA). This multiple regression model explained 79.8% of the variation.

Keywords: Muscle Architecture, Vastus Laterialis, Pennation Angle, Fascicle Length, Muscle Thickness, Ultrasound

INTRODUCTION

In layman's terms, the quadriceps is engaged anytime you straighten a flexed knee. They assist you with your daily activities, such as getting up from a chair, walking, climbing stairs, and squatting. Whenever you kick a ball, run, get up, or do any other activity that requires you to straighten your legs at the knee joint, you extend your knee. The quadriceps is heavily engaged heavily while walking or running downhill. They are used in sports like basketball, football, and handball, as well as cycling etc.

The human body's most voluminous muscle is the quadriceps femoris. The quadriceps femoris is a hip flexor and a knee extensor that is found in the lower leg. It is made up of four separate muscles: three vastus muscles and one rectus femoris (hamstring muscle). They make up the majority of the thigh's mass, and collectively, they are one of the body's most strong muscles.

Quadriceps femoris is located in anterior compartment of thigh. The four muscles of quadriceps group are Rectus Femoris, Vastus Medialis, Vastus Lateralis and Vastus Intermedius. **(Lucinda Hampton, 2021)**.

Gans and De Vries were the first to describe muscle architecture. Muscle architecture refers to the macroscopic arrangement of muscle fibres that controls a muscle's mechanical function. **(Salimin, 2018)** Muscle architecture parameters include physiological cross-sectional area (PCSA), Pennation angle (PA), Fiber Length/ Fascicle Length (FL), and Muscle Thickness (MT).

[1*]Phd, Scholar, Dept. of Exercise Physiology, LNIPE, Gwalior
[2]Assistant Professor, Dept. of Exercise Physiology, LNIPE, Gwalior

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)** Pennation angle is defined as the angle between a fascicle's orientation and the tendon axis.**(Salimin, 2018)** 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)** Muscle thickness is defined as the thickness between two fascias of muscle. In general thickness considered as the main factor for determining muscle size. **(Abe et al., 2001)**

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; M M Bamman, B R Newcomer, D E Larson-Meyer, R L Weinsier, 2000)** 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)** 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)**. 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)**

Muscle architecture has been correlated to running, squatting, lunging and jumping ability in a variety of earlier studies. **(Abe et al., 2001; Kumagai et al., 2000; Salimin, 2018)** The forward lunge has been shown to activate thigh muscles especially quadriceps and hamstrings. Forward lunge started with a front step followed by a backward push. It should be performed with the lead leg been brought as far as possible to the front in descent phase. The concept of specificity in training has received considerable mention and attention over the past decade.**(Fleck, S. J., & Kraemer, 2014)** Most movements in sports involve an athlete splitting apart their feet so that one foot is in front of the other. To better train the body to become functional in various directions, lunge exercise is suggested to be included in the training program.**(Sale, 1988; Tippett, S. R., 1995)**

The objective of this research was twofold. The primary objective was to examine the relationship between lunges performance and muscle thickness, fascicle length, and pennation angle of the vastus lateralis muscle. The secondary purpose of this study was to develop a multivariate regression equation using vastus lateralis muscle architecture characteristics to predict lunges performance.

MATERIAL AND METHODS

Selection of Subject

In this work of investigation a total sample comprised of 70 recreationally active 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 sample was subjected to the Dr. F. Hatfield one repetition maximum test in order to determine their muscle fiber type. 30

(N1=15 red muscle fiber group, N2=15 red muscle fiber group) out of 70 samples were retained in study for further evaluation. The selected subjects' age ranged between 12 to 19 years. Required data was collected after taking consent of concerned subject and parents of selected subject. This study was approved (File No- Academic/PhD/384/964) by Departmental Research Committee (DRC) of Lakshmibai National Institute of Physical Eduaction,Gwalior, M.P. India.

Forward Lunges

The participants were asked to stand with their feet shoulder width apart and their hands clutching a barbell put on their shoulders. They surged forward with their dominant foot, lowering their thigh until it was parallel to the ground, then returning to their starting position. They had to take a significant stride forward while in the down posture, with the leading knee not extending beyond the toes of the same leg. The non-dominant foot was not allowed to move from its initial position, and the head was required to look front in order to maintain a neutral neck posture. **(Baechle TR, 2008; Haff, Greg, Triplett, 2016; Nadzalan et al., 2018)**

Multiple RM Lunges Test

The multiple-RM testing protocol were conducted for the 1RM lunges performances following the guidelines by the National Strength Conditioning Association. **(Baechle TR, 2008)** "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)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 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 was determined by measuring the distance between the subcutaneous adipose tissue and the intermuscular contact (MT).The average of three successive frames was calculated. Repeated scanning of muscle thickness, pennation angle, and fascicle length measurements yielded intraclass correlation values varying from 0.9 to 0.996 ($p<0.001$).**(Nadzalan et al., 2017)**

STATISTICAL ANALYSIS

Pearson Correlation was performed to determine the relationship between the vastus lateralis muscle fiber architecture and the 1RM lunge performance. Multiple regression was performed to develop a multivariate regression equation using vastus lateralis muscle architecture characteristics to predict 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)**

RESULTS

Variables	Minimum	Maximum	Mean	Std. Dev.
Age (years)	14	19	17	1.25
Body Mass (kilogram)	55	72	66	5.75
Height (cm)	153	180	171.7	6.20
1 RM Lunges Score(kg)	44.50	74.80	66.71	7.52
Vastus Lateralis Pennation Angle(^{0})	15	20.9	17.56	1.85
Vastus Lateralis Fascicle Length(cm)	6.17	9.88	8.42	1.14
Vastus Lateralis MuscleThickness(cm)	1.91	2.94	2.48	0.32

Table No. 1. Descriptive statistics of physical characteristics, 1RM and Vastus Lateralis muscle architecture of selected subjects.

Table No. 1 depicts the descriptive statistics of the research participants' of physical characteristics, 1RM and Vastus Lateralis muscle architecture of selected subjects.. The selectedsubject'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. Table No. 1 also illustrates descriptivedata for 1RM Lunges tests. The 1 RM Lunges test had a mean and standard deviation of 66.71 and 7.52, respectively. The descriptive statistics of muscle architecture, including the Pennation Angle, Fascicle Length, and Muscle Vastus Lateralis (VL) are shown in Table No. 1. The mean and standard deviation of pennation angle for Vastus Lateralis (VL) was 17.56± 1.85. The mean and standard deviation of fascicle length for VL was 8.42± 1.14. The mean and standard deviation of muscle thickness for VL was 2.48± 0.32.

Muscle	Muscle Architecture	1 RM Lunges score
Vastus ateralis	Pennation Angle	-0.827*
	Fascicle Length	0.805*
	Muscle Thickness	0.501*

Table No. 2. Correlation analysis of VL muscle architectures and 1RM lunges. (*sig at 0.05) The correlation analysis between muscle architecture and 1RM score is shown in Table No. 2. There was a significant negative correlation between 1RM and the pennation angle of VL ($p < 0.05$). There was a significant positive correlation between 1RM and the fascicle length of VL ($p < 0.05$). There was a significant positive correlation between 1RM and muscle thickness ofVL ($p < 0.05$).

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.893a	.798	.774	3.57725

a. Predictors: (Constant), VL_PA, VL_MT, VL_FL
b. Dependent Variable: (Y2)

Table No. 3. Model summary along with the value of R and R square

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1310.899	3	436.966	34.147	.000[b]
	Residual	332.715	26	12.797		
	Total	1643.615	29			

a. Dependent Variable: (Y2)
b. Predictors: (Constant), VL_PA, VL_MT, VL_FL

Table No. 4. ANOVA table showing F-value of the obtained model

Model	Un standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	104.371	19.485		5.356	.000
VL_FL	3.464	.994	.529	3.485	.002
VL_MT	-7.959	3.089	-.346	-2.577	.016
VL_PA	-2.678	.629	-.659	-4.256	.000

a. Dependent Variable: (Y2)

Table No. 5. Regression coefficients of selected variables in obtained model along with their t-values

The regression model generated by SPSS are presented in Table No. 3. In the obtained model, the value of R^2 is 0.798, which is the maximum, and therefore, this model shall be used to develop the regression equation. It can be seen from Table No. 3 that in the obtained model, three independent variables, namely, VL_PA (Vastus Lateralis Pennation Angle), VL_MT (Vastus Lateralis Muscle Thickness), and VL_FL (Vastus Lateralis Fascicle Length), have been identified, and, therefore, the regression equation shall be developed using these three variables only. The R value for this model is 0.798, and therefore, these three independent variables explain 79.8% of the variations in Y2 (1 RM Lunges Score). Thus, this model can be considered appropriate to develop the regression equation. In Table No. 4, F-values for the obtained model have been shown. Since the F-value for the obtained model is highly significant, it may be concluded that the model selected is highly efficient also.

Table No. 5 shows the unstandardized and standardised regression coefficients in the obtained model. Unstandardized coefficients are also known as "B" coefficients and are used to develop the regression equation. Standardised coefficient is denoted by "ß" and is used to explain the relative importance of independent variables in terms of their contribution to the dependent variable in the model. VL_PA obtained "ß" value was greater than other variables; hence it can be
consider that VL_PA significantly contribute to the dependent variable.

In the obtained model, t-values for all the three regression coefficients are significant as their significance values (p values) are less than 05. Thus, it may be concluded that the variables VL_PA, VL_MT and VL_FL significantly explain the variations in the Y2 (1 RM Lunges Score). Using unstandardized regression coefficient (B) of the obtained model shown in table no. 5, the regression equation can be developed which is as follows:-

Y2 =104.371 + 3.464 (VL_FL) -7.959 (VL_MT)-2.678 (VL_PA)
(1 RM Lunges Score)

Hence, the present regression equation is quite dependable, since R^2 is 0.798. To put it another way, the three factors in this regression equation explain 79.8% of the total variability in the Y2 (1 RM Lunges Score).

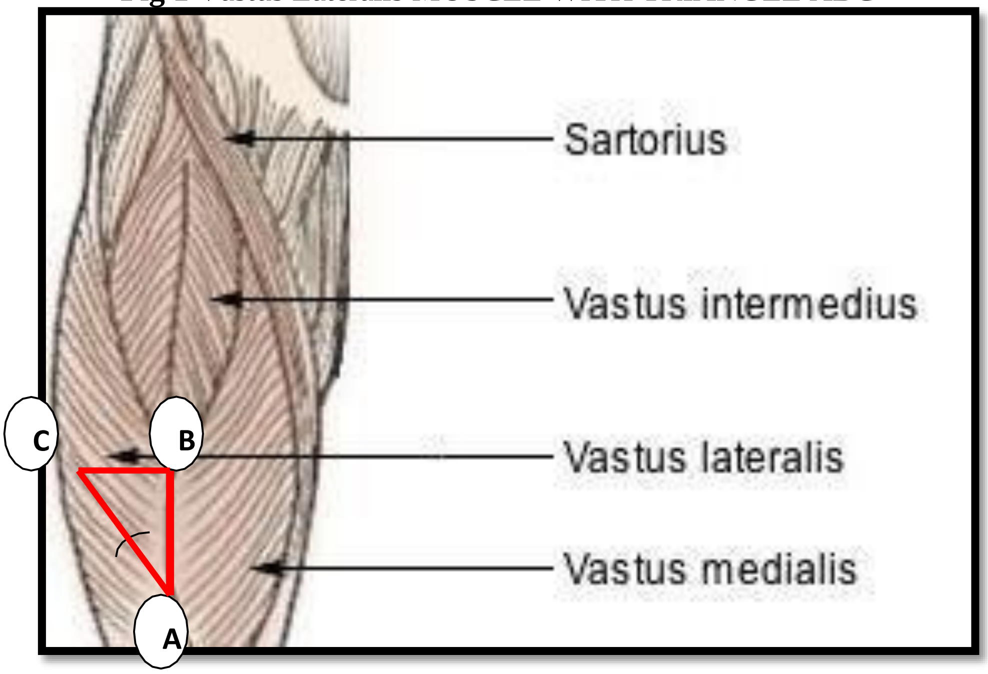
DISCUSSION ON FINDINGS

This study has shown that there are relationships between the VL muscle architectures and lunges performances. 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.

According to this research and researches completed by others the white muscle fiber group had thicker Vastus Laterialis and longer muscle fibers in their leg muscles than the red muscle fiber group, according to the research. In the leg muscles of the white muscle fiber group, the pennation angle (the angle at which a muscle contracts and shortens) is less than in the leg muscles of the red muscle fiber group. Because muscles with a larger pennation angle contract at a slower contraction than muscles with a smaller pennation angle, the white muscle fiber group has the physiological advantage of being better able to create high-speed contractions in their leg muscles.

White muscle fibers lower pennation angle, greater fascicle length and better strength production can be explained by using geometric functions also- let's assume an right angle triangle ABC on the surface of vastus laterialis as shown in figure, Where side AC represents the fascicle length, AB represents the Apo-neurosis and BC represents width of the muscle. Angle BAC represents the pennation angle (Ref Fig 1).

Fig 1 Vastus Lateralis MUSCLE WITH TRIANGLE ABC



Considering pennation angle as function of Cosine then,

$\cos\theta = \frac{AB}{AC}$, Since the cosine angle decreases the length of AC increases, which clearly establishes the lower pennation angle of muscle allows them to have larger fascicle length. Let's consider AB as $\vec{a}$, AB as $\vec{b}$ and BC as the resultant vector therefore resultant will be:-R = $\sqrt{\vec{A}^2 + \vec{B}^2 + 2\,\mathbf{AB}\cos\theta}$ As, the value of cosine decreases (Cos 17= 0.9563, Cos 16= 0.9612, Cos= 0.9659)its function value increases and overall resultant increases.

Studies by **(Abe, T., Kumagai, K. & Brechue, 2000; Blazevich, 2006; Blazevich AJ, Coleman DR, Horne S, 2009; Kumagai et al., 2000)** reported greater fascicle length of muscles represents longer sarcomeres in series, which means greater fascicle length would be beneficial when for force production at fast movement speeds which is typical properties of white muscle fibers. The increment of the length of contractile element will enable faster contraction velocity and more force that can be applied at an increasing velocity. We believe that future research comparing muscle characteristics and performance across sports will benefit from these results.

CONCLUSION

This multiple regression model explained 79.8% of the variation. The developed regression equation for predicting lunges performance was **Y2** = 104.371 + 3.464 (VL_FL) -7.959 (VL_MT)-2.678 (VL_PA). PA obtained standardized regression coefficient was maximum in terms of their contribution toward the dependent variables in the model. Muscle architecture, we believe, may be considered as a new approach evaluating muscular performances and for muscle fiber type classification in the future

REFRENCES

1. Abe, T., Kumagai, K. & Brechue, W. F. (2000). Fascicle length of leg muscles is greater in sprinters than distance runners. Med. Sci. Sports Exerc., 32, 1125–1129.
2. Abe, T., Fukashiro, S., Harada, Y., & Kawamoto, K. (2001). Relationship between sprint performance and muscle fascicle length in female sprinters. Journal of Physiological Anthropology and Applied Human Science, 20(2), 141–147. https://doi.org/10.2114/jpa.20.141
3. Baechle TR, E. R. (2008). Essentials of strength training and conditioning. Champaign. Human Kinetics.
4. Blazevich, A. J. (2006). Effects of physical training and detraining, immobilisation, growth and aging on human fascicle geometry. Sports Med., 36(12), 1003–1017.
5. Blazevich AJ, Coleman DR, Horne S, C. D. (2009). Anatomical predictors of maximum isometric and concentric knee extensor moment. European Journal of Applied Physiology, 105(6), 869–878.
6. Brughelli, M., Cronin, J., & Nosaka, K. (2010). 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, 24(3), 717–721. https://doi.org/10.1519/JSC.0b013e318197009a

a. Clark M, Lucett S, McGill E, M. I. and S. B. (2018). NASM Essentials of Personal Fitness Training.

7. Fleck, S. J., & Kraemer, W. (2014). Designing Resistance Training Programs. Human Kinetics. Haff, Greg, Triplett, N. T. (2016). Essentials of strength training and conditioning.
8. Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. Sports Med., 30, 1–15.
9. Ikegawa S, Funato K, Tsunoda N, Kanehisa H, F. T. (2008). Muscle force per cross-sectional area is inversely related with pennation angle in strength trained athletes. Journal of Strength and Conditioning Research, 22(1), 128–131.
10. K Albracht , A Arampatzis, V. B. (2008). Assessment of muscle volume and physiological cross- sectional area of the human triceps surae muscle in vivo. Journal of Biomechanics, 41(10), 2211–2218.
11. Kumagai, K., Abe, T., Brechue, W. F., Ryushi, T., Takano, S., & Mizuno, M. (2000). Sprint performance is related to muscle fascicle length in male 100-m sprinters. Journal of Applied Physiology, 88(3), 811–816. https://doi.org/10.1152/jappl.2000.88.3.811
12. Lucinda hampton. (2021). Quadriceps Muscle. Https://Www.Physio-Pedia.Com/Quadriceps_Muscle.
13. M M Bamman, B R Newcomer, D E Larson-Meyer, R L Weinsier, G. R. H. (2000). Evaluation of the strength-size relationship in vivo using various muscle size indices. Med Sci Sports Exerc., 32(7), 1307–1313.
14. Manal K, Roberts DP, B. T. (2006). Optimal pennation angle of the primary ankle plantar and dorsiflexors: variations with sex, contraction intensity, and limb. Journal of Applied Biomechanics, 22(4), 255–263.
15. Nadzalan, A. M., Mohamad, N. I., Lee, J. L. F., & Chinnasee, C. (2018). Relationship between

muscle architecture and badminton-specific physical abilities. Human Movement, 19(1), 44–50. https://doi.org/10.5114/hm.2018.73611
16. Dr. Aarushi Kataria, Dr. Naveen Nandal and Dr. Ritika Malik, Shahnaz Husain -A Successful Indian Woman Entrepreneur, International Journal of Disaster Recovery and Business ContinuityVol.11, No. 2, (2020), pp. 88–93
17. Kumar, S. (2020). Relevance of Buddhist Philosophy in Modern Management Theory.
a. Psychology and Education, Vol. 58, no.2, pp. 2104–2111.
18. Nadzalan, A. M., Mohamad, N. I., Low, J., Lee, F., & Chinnasee, C. (2017). RELATIONSHIP BETWEEN LOWER BODY MUSCLE ARCHITECTURE AND LUNGES PERFORMANCE. Journal of Sports Science and Physical Education.http://jsspj.upsi.edu.my/
19. Sale, D. G. (1988). Neural adaptation to resistance training. Medicine and Science in Sports and Exercise, 2, 135–145.
20. Salimin, N. (2018). Muscle Architecture and Exercise Performance: A Mini Review. Biomedical Journal of Scientific & Technical Research, 3(5), 5–7. https://doi.org/10.26717/bjstr.2018.03.000958
21. Tippett, S. R., & V. (1995). Functional progressions for sport rehabilitation. Human Kinetics.