How to Cite:
Tavakoli, S., Ghazi, H. R. D., Amiri, Y., Kalantari, K. K., Ghasemi, M., Baghban, A. A., Bagheri, R., & Zarepoor, F. (2022). The acute effect of common peroneal nerve electrical stimulation on quadriceps maximum activity failure in patient with knee osteo arthritis after ten physiotherapy sessions. *International Journal of Health Sciences*, *6*(S8), 350–359. https://doi.org/10.53730/ijhs.v6nS8.10259

The acute effect of common peroneal nerve electrical stimulation on quadriceps maximum activity failure in patient with knee osteo arthritis after ten physiotherapy sessions

Sadegh Tavakoli
Research and Technology Office for Students, MSc in Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Hossein Rafsanjani Deh ghazi
Research and Technology Office for Students, MSc in Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Younes Amiri
Research and Technology Office for Students, MSc in Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Khosro Khademi Kalantari*
Prof. in Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran
*Corresponding author

Mehri Ghasemi
Prof. in Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Alireza Akbarzadeh Baghban
Assoc. Prof. in Biostatistics, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Rasool Bagheri
Asst. Prof., Neuromuscular Rehabilitation Research Center, Semnan University of Medical Science, Semnan, Iran

Fatemeh Zarepoor
Research and Technology Office for Students, MSc in Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Manuscript submitted: 27 March 2022, Manuscript revised: 9 May 2022, Accepted for publication: 18 June 2022

***Abstract*---**Introduction: Knee osteoarthritis (OA) is the most prevalent OA worldwide, particularly in the USA. Studies show that knee OA leads to functional limitations, including problems with weight tolerance during walking, climbing stairs, household activities, and lightweight package transport. Since the quadriceps muscles play a critical role in weight tolerance throughout the knee joint, weakness in these muscles diminishes the capacity to protect the knee and results in knee susceptibility to more physical stress and developed structural injuries. Abnormal quadriceps muscle functioning that often manifests into weakness is part of a movement disorder presumably due to certain neurological conditions such as Parkinson's disease (PD), stroke, etc., or knee injuries after surgery, arthritis, traumatic injuries, and more. This weakness can originate from atrophy or neural inhibition that prevents maximal activation of the quadriceps muscle. This condition is called arthrogenic muscle inhibition (AMI), which Hopkins first introduced in 1990. AMI is associated with several causes, including swelling, inflammation, pain, joint stiffness, and structural damage, though the importance of these causes remains unclear. Consistently, this phenomenon is caused by discharging the sensory receptors in the damaged knee joint. Hence, AMI of the quadriceps muscle has troubled therapists and can lead to atrophy and delay or even impede the proper rehabilitation process. Methods: This study investigated 15 patients with grades 2 and 3 OA (BMI class 2 and 3; mean age of 7.52 years; mean pain intensity of 7.46). Participants were selected based on the VAS scale by the simple non-probability sampling method. In two stages, the quadriceps muscle activation capacity was recoded using the quadriceps muscle extensor torque parameter. The maximum autonomic effort to activate the maximum quadriceps muscle was also recorded. After resting for five minutes, synchronizing the electrical stimulation of the common peroneal nerve at the fibula head with the maximum autonomic effort of the individual to maximize the quadriceps muscle was investigated. Results: Quadriceps muscle extensor torque was significantly increased ($p < 0.05$) upon synchronizing electrical stimulation of the common peroneal nerve with a maximal autonomic effort to activate quadriceps muscle, compared to synchronizing electrical stimulation of quadriceps muscle with the maximal autonomic attempt to activate the quadriceps muscle. Conclusion: The defect of maximal quadriceps muscle activity, which, as a protective mechanism in the early stages of knee joint injury, hinders the maximal movement of this muscle, can be diminished by stimulating the common peroneal nerve at the fibula head with low intensity, which leads to an arousal reflex between the pretibial and quadriceps muscles.

***Keywords*---**inhibition, quadriceps, knee joint injury, functional defect, common peroneal nerve, knee osteoarthritis.

Introduction and goals

Knee osteoarthritis (OA) is the most prevalent type of OA worldwide, particularly in the USA [1-2]. According to reports, knee OA leads to functional limitations, including problems with weight tolerance during walking, climbing stairs, household activities, and lightweight package transport [3]. Since the quadriceps muscles play a critical role in weight tolerance throughout the knee joint, weakness in these muscles reduces the capacity to protect the knee and results in knee susceptibility to more physical stress and developed structural injury [4]. As mentioned above, weakness in quadriceps muscles directly contributes to knee pain and may influence postural balance and oscillation in patients with knee OA [3, 4]. According to studies, weakness in quadriceps muscles could exert many adverse effects on physical function and inability over time in patients with knee OA [5]. However, according to Slemenda et al., some OA patients have weakness in their quadriceps femoris muscle even if they do not develop pain or atrophy [6, 7]. This finding indicates that pain and disuse atrophy alone fail to weaken the quadriceps femoris muscle in individuals with knee OA, and other mechanisms in patients with knee OA may contribute to quadriceps muscle weakness. In a study by Hurley and Newham, some patients with knee OA were fully disabled in activating their quadriceps muscles, a condition is known as a quadriceps activity failure (QAF) [8].

In another study, when applying QAF, the autonomic reduction of the maximum isometric output of the quadriceps muscle torque was observed. This result was compared with the isometric output of the quadriceps muscle contraction produced by the superimposition provided by the electrical device. Although QAF is associated with joint effusion in patients with knee injuries, according to researchers, some patients with knee OA who develop QAF do not manifest joint effusion symptoms [10]. Kristen et al. reported that degenerative changes in the knee joint OA structure might originate from changes in sensory information from the joint mechanoreceptor, where the quadriceps muscle activation capacity may be reduced. In a study on patients with knee OA who develop QAFs, compared with controls in terms of gender, age, and activity, QAF was associated with more quadriceps muscle dysfunction with reduced strength and reduced physical performance and functions [11, 12].

Research has revealed that the severity of the quadriceps muscle contraction can significantly affect the reaction's incidence, so the reaction is inhibited during the rest of the muscle where there is no contraction. Given the critical quadriceps femoris muscle role in weight tolerance, minimizing the activation of this muscle is among the most significant and primary rehabilitation goals [13, 23, 15]. By underscoring central activation mechanisms, this study proposes a new method to evaluate and treat this problem via a deep understanding of this phenomenon, the nervous mechanisms involved, and the proposed therapeutic interventions.

Materials and Methods

This study investigated 15 randomly selected volunteers affected by knee OA, including nine (66.7%) males and six (33.3%) females. OA has affected the right leg in 60% of patients and the left leg in 40%. The mean age of participants was

50.53 years (SD = 12.31). All participants had knee OA referred to the physiotherapy clinic affiliated with the Rehabilitation School, Shahid Beheshti University of Medical Sciences. Exclusion criteria were having skeletal-musculoskeletal abnormality that limits the motor ability of lower limbs, neuromuscular abnormality, cardiovascular abnormality, a history of certain neurological condition, and not having regular professional exercise in the past year. Participants' height, weight, and body mass index (BMI) were measured, and median, standard deviation (SD), age range, and demographic characteristics were checked and recorded.

The electrical nerve stimulator used was a separate dual-channel stimulator model P710 (NOVIN medical engineering Co.). The rectangular stimulation wave was applied with a pulse duration of 100 µs at 40 Hz. The electrodes were monopolar and spontaneously attached to the skin. The quadriceps muscle was stimulated by placing the active electrode (cathode) on the muscle bulk and the anode on the femoral nerve direction proximal to the cathode. The common peroneal nerve was stimulated by a 3.2 cm in thickness cathode at the fibula head. The larger electrode (anode) was rectangular and placed nearly 2 cm distal to the cathode.

The cathode electrode was placed on the skin to allow desired deep peroneal nerve stimulation. This can be achieved by dislocating the electrode to create the most minor motor threshold for innervated muscles (tibialis anterior muscle, extensor digitorum muscle, extensor pollicis longus muscle, peroneus tertius). This stimulation leads to dorsiflexion of the ankle. The electrical stimulation intensity required to stimulate the common peroneal nerve is defined based on the motor threshold of the tibialis anterior muscle. In all tests, the aim is to achieve the highest reflex in distinct hip and knee joint positions, which often occurs at the last 15° of knee extension and 110° of hip flexion. The desired stimulation intensity to achieve the highest reflex was two times the motor threshold. Notably, motor threshold changes with each sudden foot movement, which can be due to dislocation of the cathode electrode and the movement of muscles under the electrodes.

An eight-channel surface electromyography device (Data log, Biometrics, UK) was used to record participants' generated force (kg). The dynamometer was set on one of the channels of the electromyographic device, and the rate of power generated by the quadriceps muscle was observed and recorded at various stages of the test. Participants' information, including height (measured by a measuring tape), weight (measured by a scale), age, BMI, and other demographic information, were calculated and recorded in the relevant forms.

Table 1. Statistical indices of the background variables (n = 15)

	Mean	Min	Max	SD
Age (year)	35	50.53	12.31	73
Height (m)	164	172.33	6.77	188
Weight (kg)	64	78.33	9.73	96
BMI (kg/m^2)	22.34	26.35	2.80	30.30

Participants were then seated on a chair designed to assess the extensor torque of the knee (Figure 1). This device was first tested by Rezasoltani et al. in the biomechanics laboratory at the Faculty of Rehabilitation Sciences [16] (Sws ≤ 9.1 N, ICCs ≥ 0.90). This study was conducted in two stages, each under particular conditions. Before any intervention, the motor threshold of the tibialis anterior muscle and the intensity required to make the most tolerable contraction of the quadriceps muscle (pain threshold) were estimated for each individual. The output of the devices was then switched off for each current.

Then, to warm up the quadriceps muscle and get informed of the test conditions, each participant performed 20 contractions with the submaximal intensity while sitting on a chair, i.e., the last 15° of knee extension and 110° hip joint flexion (Figure 1).

Figure 1: The patient's sitting position

This study was performed in two stages, each under particular conditions. Before any intervention, the motor threshold of the tibialis anterior muscle and the intensity required to make the most tolerable contraction of the quadriceps muscle (pain threshold) were estimated for each individual. The output of the devices was then switched off for each current. Then, to warm up the quadriceps muscle and get informed of the test conditions, each participant performed 20 contractions with the submaximal intensity while sitting on a chair, i.e., the last 15° of knee extension and 110° hip joint flexion

Data were analyzed at a significance level of α=0.05. The study used a paired t-test (for normally distributed data) and its non-parametric equivalent Wilcoxon signed-rank test (for non-normally distributed data) to compare the maximum muscle torque before and after the common peroneal nerve electrical stimulation. The normality of data distribution was investigated using the Shapiro–Wilk test. Descriptive statistical methods such as tables, graphs, and statistical indicators were also employed. Graphs were drawn in Excel 2010 software, and results were extracted in SPSS18.

Results

Table 2 indicates the normal distribution of data on the maximum extensor torque of the quadriceps muscle obtained using the Shapiro–Wilk test. According to the Shapiro–Wilk test data, the paired t-test was employed to measure the data obtained from different study stages.Table 3 compares data from different stages of the study based on the paired t-test. The highest extensor torque of the quadriceps muscle synchronized with electrical stimulation of the common peroneal nerve in patients with knee OA was significantly high compared to the highest extensor torque of the quadriceps muscle synchronized with electrical stimulation of the quadriceps femoris muscle) (p = 0.023).

According to Table 3, the mean torques of the quadriceps femoris muscle when synchronized with electrical stimulation of the common peroneal nerve were nearly 4.5 times greater than the mean torques of the quadriceps femoris when synchronized with electrical stimulation of the quadriceps muscle. Electrical stimulation of the common peroneal nerve seems to hold a greater capacity to increase the extensor torque of the quadriceps femoris muscles when synchronized with the most autonomic effort of participants than direct electrical stimulation of the quadriceps femoris muscle (p = 0.023).

Table 2. Normality of data (the Shapiro–Wilk test) (n = 15)

	Sig.	Statistic
First torque (*)	0.918	0.182
Second torque (**)	0.918	0.179

* Extensor torque of the quadriceps femoris muscles with electric stimulation of the quadriceps femoris muscles
** Extensor torque of the quadriceps femoris muscles with electric stimulation of the common peroneal nerve

Table 3. Measurements reliability indices (n = 15)

	SEM	SDD	95% CI for ICC	p-value
			Upper limit/ lower limit	
First torque (*) Second torque (**)	1.751	1.781	0.712 / 8.222	0.023

ICC: Intraclass correlation coefficient; SEM: standard error of measurement; SDD (smallest detectable difference)

* Extensor torque of the quadriceps femoris muscles with electric stimulation of the quadriceps femoris muscles
** Extensor torque of the quadriceps femoris muscles with electric stimulation of the common peroneal nerve

Discussion

This study investigated the prompt impact of electrical stimulation of the common peroneal nerve on the maximum activation capacity of the quadriceps femoris muscle in patients with knee OA. Neuromuscular activation failure or inhibition of the quadriceps femoris muscle, mainly caused by knee joint injuries due to trauma, knee joint surgeries, knee joint arthritis, etc., is a protective mechanism to prevent further knee joint injuries in the early stages. Such an inhibition plays a protective role in the early stages but disrupts the efficient rehabilitation process with time. Numerous studies report a reactive relationship between the pretibial muscles and the quadriceps femoris muscle.

As a well-established theory, the inputs of the descending system stimulate this response pathway, in which the intensity of muscular activities and using motor units of the quadriceps femoris muscle increase with an increase in the power of descending inputs. In addition, the relationship between the power of descending inputs and the intensity of quadriceps femoris muscle activity is bilateral, implying that the reaction will be more effective with a rise in the autonomic activity of the quadriceps femoris muscle contraction. Furthermore, the rate and intensity of this reflex change at different angles of the knee joints, with the maximum intensity found at the end of the knee joint extension and the end of the hip joint flexion. This reaction has a low motor threshold in the excitation amplitude of the Type 1 movement fibers. The reaction's low excitation threshold indicates a high excitation speed of afferents involved, confirming the role of group I afferent fibers in this reaction. These peritubular Group 1 afferents originate from the Golgi tendon organ (Ib) and the muscle spindle (Ia). However, most studies support the more prominent role of Ib group afferents in this reflex.
According to studies, the quadriceps femoris muscle contraction intensity can substantially affect the incidence of this reaction so that this reaction is inhibited during resting with no contraction. Concerning the importance of the quadriceps femoris muscle during weight-tolerance activities, minimizing the activation failure of this muscle is among the most critical and primary goals of the rehabilitation phase.

The reaction's functional role is well depicted when a person walks on a treadmill at a constant speed. The reaction approaches its maximum at the end of the swing stage and the onset of the stane stage. However, it will disappear entirely between the mid-stance and terminal swing phases. According to our study, indirect stimulation of the quadriceps femoris muscle by electrical stimulation of the common peroneal nerve (CPQ reaction activation) achieves better results than amplification by the direct electrical stimulation of the muscle bulk. This is crucial when direct electrical stimulation of the quadriceps is not achievable or when a more relevant and effective strengthening of the quadriceps femoris muscle is required. We can achieve more data on this sensory-motor dysfunction by conducting more research on the nature and structural features of the CPQ reaction. Furthermore, additional research on the reaction pathway between the peritubular and quadriceps femoris muscles can assist in studying other muscles in the body.

Conclusion

Studies have shown that the quadriceps femoris muscle contraction intensity can significantly affect the incidence of this reaction so that this reaction is inhibited during resting with no contraction. Concerning the importance of the quadriceps femoris muscle during weight-tolerance activities, minimizing the activation failure of this muscle is among the most critical and primary goals of the rehabilitation phase. The maximum quadriceps femoris muscle activation failure plays a protective role in the early stages, but it disrupts the effectiveness of this muscle during functional activities over time. Therefore, besides conventional rehabilitation interventions to reduce this activation defect, electrical stimulation of the common peroneal nerve at the fibula head can reduce quadriceps femoris muscle activation failure in people with knee OA.

Acknowledgments

This manuscript is a product of the master's thesis in physiotherapy conducted by Sadegh Tavakoli under the supervision of Dr. Khosrow Khademi Kalantari and Dr. Mehri Ghasemi. We thank and appreciate all those who contributed to this research.

References

1. Saptarini NM, Hadisoebroto G, Wibowo MS, Gusdinar T. Effect of drug treatment on serum Cartilage Oligomeric Matrix Protein levels in patients of Rheumatoid Arthritis and Knee Osteoarthritis in Bandung, Indonesia. Journal of Advanced Pharmacy Education & Research| Apr–Jun. 2020;10(2):41-45
2. Farhadian M, Morovati Z, Zadeh FQ, Shamsoddini A. The Effect of Kinesio Taping on the Hand Functions and Symptoms in Patients with Hand Osteoarthritis (a Preliminary Study). International Journal of Pharmaceutical and Phytopharmacological Research. 2019;9(4):75-80.
3. Ibrahim S, Ahmed SA, Ahmed SM, Ahmed SK. Osteoarthritis: The Effect of Specific Watsu Therapy on Peak Torque and Functional Parameters-An Analytical Study. Pharmacophore. 2020 Sep 1;11(5):46-50.
4. Hopkins JT, Ingersoll. Arthrogenic muscle inhibition: a limiting factor in knee joint rehabilitation. J Sport Rehabil. 1990;9:135–159.
5. Bergmans J, Delwaide PJ, Gadea-Ciria M. Short-latency effects of low-threshold muscular afferent fibers on different motoneuronal pools of the lower limb in man. Exp Neurol.1978; 60: 380–385.
6. Binder-Macleod, Lee KMP, Lynn Snyder-Mackler and Stuart A, Scott K Stackhouse JES, Samuel CK. Maximum Voluntary Activation in Nonfatigued and Fatigued Muscle of Young and Elderly Individuals. Journal of Athletic Training. 2001;26:1102-9.
7. Riann M.Palmieri a, 1, James A.Tom b, Jeffery E.Edwards c, Arthur Weltman d,, Ethan N.Saliba e DJMe, Christopher D.Ingersoll e. Arthrogenic muscle response induced by an experimental knee joint effusion is mediated by pre- and post-synaptic spinal mechanisms. Journal of Electromyography and Kinesiology. 2004;14:631–40.
8. John Haleem KPaPA, Lars L Andersen, Michael Nielsen. Exercises: Implications for Rehabilitation Therapeutic Exercises and Heavy Resistance Neuromuscular Activation in Conventional. Journal of Athletic Training. 2006;86:683-97.
9. Dvid Andrew Rice, Peter John McNair.Quadriceps Arthrogenic Muscle Inhibition: Neural Mechanisms and Treatment Perspectives. Elsevier. 2010;40:250-66.
10. Kristen A. Scopaz, Sara R. Piva, Alexandra B. Gil, Jason D., Woollard M, Chester V. Oddis, and G. Kelley Fitzgerald. The Effect of Baseline Quadriceps Activation on Changes in Quadriceps Strength After Exercise Therapy in Subjects with Knee Osteoarthritis. NIH Public Access. 2009;61:951-7.

11. Brian G. Pietrosimone P, Susan A. Saliba P, Joseph M. Hart P, ATC 3, Jay Hertel P, ATC 4, Christopher D. Ingersoll P, ATC 5. CONTRALATERAL EFFECTS OF DISINHIBITORY TENS ON QUADRICEPS FUNCTION IN PEOPLE WITH KNEE OSTEOARTHRITIS FOLLOWING UNILATERAL TREATMENT. North American Journal of Sports Physical Therapy. 2010;5:111-20.
12. David A Rice* PJMaGNL. Mechanisms of quadriceps muscle weakness in knee joint osteoarthritis: the effects of prolonged vibration on torque and muscle activation in osteoarthritis and healthy control subjects. Journal compilation The Physiological Society. 2011;61:142-56.
13. ANDREW D. LYNCH PDAVID S. LOGERSTEDT, MICHAEL J. AXE,, MD3 aLS-M,. Quadriceps Activation Failure After Anterior Cruciate Ligament Rupture Is Not Mediated by Knee Joint Effusion. NIH Public Access. 2012;42:510-2.
14. KHOSRO k. Kalantari1, Ronald H. THE GAIN MODULATION OF THE HETERONYMOUS EXCITATION OF QUADRICEPS WITH CHANGES IN POSITION OF THE KNEE AND HIP JOINTS IN HUMANS, pak j med sci octeber – December 2007 vol.23 no 5 805-808
15. KHOSRO k. Kalantari1, Ronald H. baxendale2, Asghar Rezasoltani. THE INHIBITION OF SHORT LATENCY REFLEX LINKING THE PRETIBIAL MUSCLE TO QUADRICEPS MOTONEURONUES DURING STANCE TO SWING TRANSITION IN HUMANS. Pak j med sci January – march 2001 vol.27 No. 1 162-
16. DAVID RICE PJM, 1 AND NICOLA DALBETH2. Effects of Cryotherapy on Arthrogenic Muscle Inhibition Using an Experimental Model of Knee Swelling. Arthritis & Rheumatism (Arthritis Care & Research). 2009;61:78-83.
17. EricD . McVey MERP. Arthrogenic Muscle Inhibition n the Leg Muscles of Subjects Exhibiting Functional Ankle Instability. American Orthopedic foot & Ankle Society' lnc. 2005;86:l4 10-494.
18. Brooke, J. D. and McIlroy, W. E. (1990a) Movement modulation of a short latency reflex linking the lower leg and the knee extensor muscles in humans. Electroerrcephc.lin.Neurophysiol7. 5,6674.
19. Jean-Charles Lamy1, Caroline Iglesias1,2, Alexandra Lackmy1,2, Jens Bo Nielsen3, Rose Katz1,2, and V´eronique Marchand-Pauvert1. Modulation of recurrent inhibition from knee extensors to ankle motoneurones during human walking. Journal compilation The Physiological Society. 2008;24:5931-46.
20. G. KELLEY FITZGERALD AND TERENCE W. STARZ2 Quadriceps Activation Failure as a Moderator of the Relationship Between Quadriceps Strength and Physical Function in Individuals With Knee Osteoarthritis Arthritis & Rheumatism (Arthritis Care & Research) Vol. 51, No. 1, February 15, 2004, American College of Rheumatology
21. Slemenda C, Brandt KD, Heilman DK, Mazzuca S, Braunstein EM, et al. Quadriceps weakness and osteoarthritis of the knee. Ann Intern Med 1997;127:97–104.
22. Hurley MV, Scott DL, Rees J, Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. Ann Rheum Dis 1997;56:641–8.
23. Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis 2001;60:612–8.

24. Hurley MV, Newham DJ. The influence of arthrogenous muscle inhibition on quadriceps rehabilitation of patients with early, unilateral osteoarthritic knees. Br J Rheumatol 1993;32: 127–31.
25. Pierrot-Deseilligny E, Morin C, Bergego C, Tankov N. Pattern of group I fibre projections from ankle flexor and extensor muscles in man. Exp Brain Res. 1981; 42(3-4):337–350.
26. Snyder-Mackler L, De Luca PF, Williams PR, Eastlack ME, Bartolozzi AR 3rd. Reflex inhibition of the quadriceps femoris muscle after injury or reconstruction of the anterior cruciate ligament. J Bone Joint Surg Am 1994;76(4):555-60.
27. Urbach D, Nebelung W, Weiler HT, Awiszus F. Bilateral deficit of voluntary quadriceps muscle activation after unilateral ACL tear. Med Sci Sports Exerc 1999;31(12):1691-6.5.
28. Yong-Jun Cha, Isokinetic Training Effect of Ankle Positions on Knee Extensor Strength Published online 2014 Sep 17. J Phys Ther Sci. 2014 Sep; 26(9): 1465–1467.
29. Ty Hopkins, Christopher D. Ingersoll, Jeffrey Edwards and Thomas E. Klootwyk. Cryotherapy and Transcutaneous Electric Neuromuscular Stimulation Decrease Arthrogenic Muscle Inhibition of the Vastus Medialis After Knee Joint Effusion J Athl Train. 2002 Jan-Mar; 37(1): 25–31.
30. Khosro K Kalantari, Rhonald H. Baxendale. The pattern of modulation of short latency reflex linking the pretibial muscles to the knee extensors during gait in human. Pak J Med Sci Jan - Mar 2009;25(1):31-5.8.
31. Palmieri, R.M., Villwock M., Zernicke R. F. Pain and Effusion and Quadriceps Activation and Strength. Journal of Athletic Training. 2013; 48(2), 186 - 191.
32. A. Jegu, B Pereira, N Andant, E Coudeyre. Effect of eccentric isokinetic strengthening in the rehabilitation of patients with knee osteoarthritis: Isogo, a randomized trial, 2014 - biomedcentral.com
33. Parmin, P., Suarayasa, K., & Wandira, B. A. (2020). Relationship between quality of service with patient loyality at general polyclinic of kamonji public health center. *International Journal of Health & Medical Sciences*, *3*(1), 86-91. https://doi.org/10.31295/ijhms.v3n1.157
34. Widana, I.K., Sumetri, N.W., Sutapa, I.K., Suryasa, W. (2021). Anthropometric measures for better cardiovascular and musculoskeletal health. *Computer Applications in Engineering Education*, *29*(3), 550–561. https://doi.org/10.1002/cae.22202