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Original Article

Identification of the risk of anterior cruciate ligament injury by muscle strength balance assessment

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ABSTRACT

This study aims to identify the risk of anterior cruciate ligament (ACL) injury in petanque athletes at Jakarta State University (UNJ). This research is a quantitative descriptive study using a cross-sectional survey design. There were 18 research subjects consisting of 10 male athletes and 8 female athletes. Characteristics of research subjects such as body weight and Body Mass Index (BMI) were measured using the Xiaomi MI scale. Assessment of hamstring and quadriceps muscle strength is assessed using an electromyography (EMG) tool when performing manual muscle testing (MMT). The research results showed that the research subjects had a normal BMI category, namely 22.31 for men and 22.09 for women. Statistically, there were no significant differences in hamstring and quadriceps muscle strength in the right (p=0.448) and left (p=0.376) legs for male subjects. Meanwhile, for female subjects, there was also no significant difference found between hamstring and quadriceps muscle strength on the right (p=0.429) and left (p=0.232) legs. Thus, it can be concluded that UNJ petanque athletes have a low risk of ACL injury, because they have hamstring and quadriceps muscle strength that is not significantly different (balanced), and is supported by a normal BMI category. Further studies need to be carried out by combining and considering other variables in identifying the risk of ACL injury.

Keyword: *anterior cruciate ligament injury*, *electromyography*, muscle strength balance

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INTRODUCTION

Sports injuries are often experienced by athletes which causes athletes to experience a decrease in their level of physical activity (Emery & Pasanen, 2019; Yuliana & Kushartanti, 2020), psychological pressure (Chan et al., 2017), even career-ending athlete (Ristolainen et al., 2012). Sports injuries often occur in the lower extremities with an incidence rate of 53%, followed by 35% of upper

extremity injuries, 12% of which occur in the head, neck and trunk (Sytema et al., 2010).

Anterior Cruciate Ligament (ACL) injury is an injury to the lower extremities, namely to one of the ligaments located in the knee joint. The percentage of ACL injuries is quite high in athletes and is mostly caused by non-contact sports, reaching 70-80% (Acevedo et al., 2014). ACL injuries cause several problems, such as knee joint imbalance (Fernandes et al., 2016), decreased level of exercise (Arundale et al., 2018), a long recovery process (Zaffagnini et al., 2015), even if no proper treatment is received actually increases the risk of re-injury (Beischer et al., 2020), and over a long period of time the risk of experiencing knee osteoarthritis and lower extremity dysfunction (Zebis et al., 2009). Therefore, early identification of the risk of ACL injury in athletes is important, as a strategy for primary prevention, that is, injuries are prevented before they occur. In addition, it helps athletes to achieve maximum performance, without being hampered by functional impairment due to sports injuries.

Hamstring and quadriceps muscle strength imbalances are often used to detect the risk of knee-related injuries (Ruas et al., 2019). In line with other research which states that hamstring-quadriceps imbalance is associated with non-contact foot injuries in athletes (Kim & Hong, 2011). Meanwhile, the risk of ACL injury is associated with decreased hamstring strength, but not the quadriceps muscle (Myer et al., 2009) or differences in the average activity of the vastus lateralis and semitendinosus muscles (Zebis et al., 2009).

Assessment of the balance of quadriceps and hamstring muscle strength against the increase in risk of knee injury from year to year often uses the quadriceps-to-hamstrings (Q/H) ratio. The most popular assessment of the Q/H ratio is assessed using the isokinetic test (Coombs & Garbutt, 2002; Myer et al., 2009; O'donnell et al., 2020). Therefore, this study will measure the balance between hamstring and quadriceps muscle strength through electromyography (EMG) measurements.

Electromyography (EMG) is a tool that can record muscle activity and is widely used in the fields of Sports Science and Sports Medicine (Lee et al., 2022). EMG via electrodes attached to the surface of the skin will translate the signals

resulting from muscle activity when contracting into graphs that can be viewed using EMG analysis software (Lee et al., 2022). Normally, EMG signals will be seen when carrying out a conscious maximum contraction or Maximum Voluntary Contraction (MVC) with the support of maximum isometric movements in each muscle (Cho et al., 2022). Several studies use EMG to analyze muscle strength (Wang et al., 2022), muscle activation (Lee et al., 2022), and injury risk analysis (Duan, 2021; Hewett et al., 2005).

Petanque is a non-contact sport played by throwing an iron ball forward toward a wooden ball (jack) to get points, and throwing an iron ball toward the opponent's ball so that the opponent's ball moves away from the jack (Pelana et al., 2021). There are two position techniques for throwing iron balls in the sport of petanque, namely, standing position and squatting position (Pelana et al., 2020). In the sport of petanque, the lower extremities, especially the knee joints, have an important role. Petanque athletes who throw in a squatting position use their strongest leg as support (Pelana et al., 2020). This position makes the lower extremities, especially the knee joints, work harder because it functions as a support for body weight and keeps the body's balance stable. Bearing in mind that the lower extremities, especially the knee joint, have an important function for the body, namely that they must support the body's weight (Vaienti et al., 2017). Meanwhile, the effects of an ACL injury can disrupt an athlete's physical abilities and even threaten an athlete's career. In Indonesia, research assessing the risk of ACL injury in petanque athletes is still very limited. Thus, this study aims to identify the risk of ACL injury in petanque athletes at Jakarta State University by assessing the balance of hamstring and quadriceps muscle strength.

METHOD

Universitas Negeri Jakarta petanque athletes totaled 24, consisting of 13 male athletes and 11 female athletes. However, there were 18 athletes who met the criteria to be the subject of this study, consisting of 10 men and 8 Female. Research subjects were selected based on predetermined inclusion criteria, namely active as petanque athletes at Universitas Negeri Jakarta and willing to become research subjects marked by signing an informed consent. Meanwhile, the exclusion criteria

for this study were participating in sports other than petanque, and having a history of knee or lower extremity injuries that interfered with activities.

A total of 18 research subjects who met the criteria for this research signed informed consent. Furthermore, information related to the characteristics of research subjects such as body weight and BMI was measured using the Xiaomi MI scale 2 which has been proven to have validity as a tool for measuring body composition (Alidadi et al., 2019). The standard for measuring body composition is that research subjects are in good health with a stable water and electrolyte balance (Kyle et al., 2004). Subjects were asked not to eat, drink and do physical activity for at least 3 hours before measurement, and to keep their bladder empty (Domaradzki & Koźlenia, 2022). Before taking measurements, the subject first rested for 30 minutes and wore a light cloth without metal (Alidadi et al., 2019).

Finally, EMG was used in this study to see the strength of the hamstring and quadriceps muscles from the peak values produced when performing manual muscle testing (MMT) with maximum isometric contractions. MMT on the quadriceps muscle group is carried out in a sitting position with the knee extended at 45^0 from knee flexion (Lee et al., 2022) and EMG electrodes are attached to the quadriceps muscle. Meanwhile, MMT on the hamstring muscle group is carried out in a prone position, the knees are bent (flexed) to 75^0 (Lee et al., 2022) and the EMG electrode is attached to the hamstring muscles. Research subjects performed three trials and each isometric contraction lasted 5 seconds with a 30-second rest between each trial (Navacchia et al., 2019).

Data were analyzed using SPSS version 26. Basic characteristics were analyzed using descriptive statistics such as number, mean, percentage and standard deviation. Data normality uses the Shapiro-Wilk Test. Next is the Independent Samples Test to determine the difference in the average peak values of the hamstring and quadriceps muscles. Meanwhile, the Malen-Whitney test is used for data that is not normally distributed. The significance level was set at $p<0.05$.

RESULT AND DISCUSSION

Result

This study used 18 subjects, consisting of 10 male and 8 female, and met the criteria for being the subject of this study. Data on the characteristics of the research subjects are presented in Table 1.

Tabel 1. Data on Research Subject Characteristaics Grouped by Gender

Characteristics	Male	Female
Gender, n (%)	10 (55,56)	8 (44,44)
Age	21,9 ± 2,28	21,13 ± 3,87
Height (cm)	169,4 ± 6,20	155,87 ± 3,64
Body Mass Index (BMI)	22,31 ± 3,77	22,09 ± 4,41

Data are presented as mean ± standar devation

Tabel 2. Results of Data Analysis of Peak Hamstring and Quadriceps Muscle Values for Study Subjects

Gender	Variabel	N	Mean	Std. Deviation	*P-Value*
Male	Left Quadricep	10	346,5	1,98	0,376
	Left Hamstring	10	347,2	1,59	
	Right Quadricep	10	350,6	7,19	0,448
	Right Hamstring	10	347,7	1,54	
Female	Left Quadricep	8	350,1	5,18	0,232
	Left Hamstring	8	347,7	2,12	
	Right Quadricep	8	350,1	7,77	0,429
	Right Hamstring	8	347,0	2,33	

The results of the data analysis of the peak values of the hamstring and quadriceps muscles of the research subjects which were measured using EMG by performing maximum isometric contractions during manual muscle testing (MMT) concluded that there was no significant difference found between the strength of the hamstring and quadriceps muscles on the right and left sides in male and female research subjects. This is evidenced by each value of $p > 0.05$. Thus, it can be stated that the strength of the hamstring and quadriceps muscles on each side of the leg in men and women has the same or balanced strength. The peak values for the hamstring and quadriceps muscles of the research subjects are also presented in figures 1 and 2.

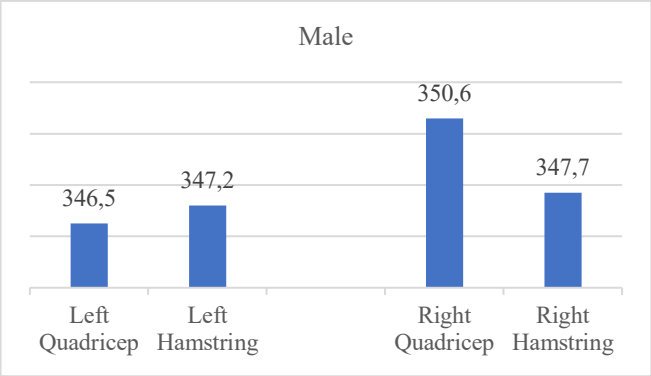

Figure 1. Peak values for the hamstring and quadriceps muscles of male subjects

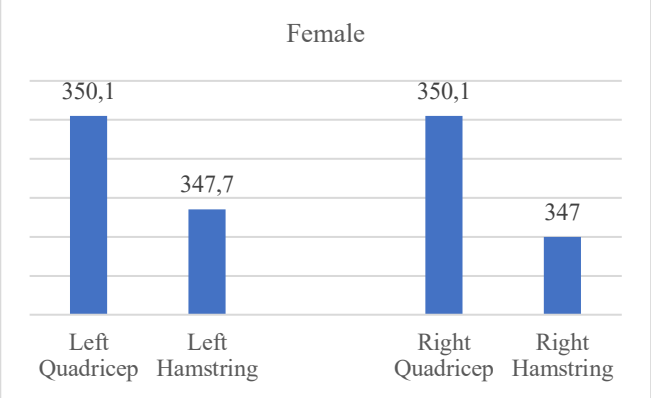

Figure 2. Peak values for the hamstring and quadriceps muscles of male subjects

Discussion

Sports injuries can happen to anyone, both in contact and non-contact sports. This study aims to identify the risk of ACL injury in petanque athletes at Jakarta State University. Based on the data presented in Table 1, male research subjects amounted to 55.56% and female research subjects amounted to 44.44%. On average, male and female research subjects had a normal BMI category, namely 22.33 for male subjects and 22.09 for female subjects. Previous research states that a high BMI or teenagers who are overweight/obese are associated with an increased risk of knee injury, compared to normal weight (Richmond et al., 2016; Munthe et al., 2021). This is because excess body weight/obesity will put greater pressure/load on soft tissues and joints (Prieto-González et al., 2021). This, research subjects have a low risk of experiencing knee injury because they have a normal BMI category so that the soft tissue and joints in the knee do not receive a large load/pressure.

Meanwhile, in the data presented in Table 2, no significant differences were found between the strength of the hamstring and quadriceps muscles in male and female subjects on each side of the leg. Proven by the results of statistical analysis using the Independent t-test and Man-Whitney test (for non-normally distributed data), each showing a p-value>0.05. Previous research stated that the highest risk of causing Anterior Cruciate Ligament (ACL) injury in female athletes in the future is that there is an average difference in the semitendinosus and vastus lateralis muscles (Zebis et al., 2009). Supported by the results of other research. The imbalance of hamstring and quadriceps muscle strength is a predictor of athletes experiencing knee-related injuries (Perkins & Canavan, 2023). Hamstring muscle endurance and reduced hamstring strength relative to quadriceps endurance and quadriceps strength are factors that influence the occurrence of overuse knee injuries during competition in female collegiate athletes (Ryman Augustsson & Ageberg, 2017). The measurement results showed that there was no significant difference between the strength of the hamstring and quadriceps muscles in the research subjects, thus reducing the risk of experiencing knee injuries, especially ACL. This illustrates that there is a good relationship between agonist-antagonist strength and good knee joint stability. During knee extensor concentric strength, hamstring eccentric strength is very important to maintain knee joint stability (Ruas et al., 2019). Balanced muscle strength can significantly reduce the risk of injury (Croisier et al., 2008). The most common recommendation to reduce knee strength imbalances and injury risk is with eccentric quadriceps and eccentric hamstring exercises (Ruas et al., 2018.).

The results of this study may provide insight into the risk of ACL injury in athletes. Apart from that, it helps coaches to evaluate the strength and balance between the hamstring and quadriceps muscles, so that coaches can use it as a consideration for designing and compiling sports injury prevention programs. However, the limitations of this study are in identifying the risk of ACL injury, only assessing the variables of hamstring-quadriceps muscle strength balance and BMI. Previous research has shown the importance of combining several different screening tests (Schweizer et al., 2022), such as using alternative methods to determine the hamstring-quadriceps (H: Q) ratio while considering other

neuromuscular variables (Ruas et al., 2019). Additionally, assessing muscle strength imbalances along with other factors provides a better understanding of the relationship between hamstring to quadriceps ratio (H:Q) and injury (Kellis et al., 2022).

CONCLUSION

The results of the study showed that there was no significant difference between the strength of the hamstring and quadriceps muscles on each side of the leg in male and female research subjects. In addition, male and female subjects have a normal BMI category. Thus, it can be concluded that petanque athletes at Jakarta State University have a low risk of ACL injury. In future studies, it will be important to combine multiple screening tests and consider other variables associated with ACL injury risk.

REFERENCE

Acevedo, R. J., Rivera-Vega, A., Miranda, G., & Micheo, W. (2014). *Anterior Cruciate Ligament Injury: Identification of Risk Factors and Prevention Strategies*. www.acsm-csmr.org

Alidadi, Y., Metanati, M., & Ataie-Jafari, A. (2019). *The validity of a bioelectrical impedance analyzer, Xiaomi MI scale 2, for measurement of body composition*.

Arundale, A. J. H., Silvers-Granelli, H. J., & Snyder-Mackler, L. (2018). Career Length and Injury Incidence After Anterior Cruciate Ligament Reconstruction in Major League Soccer Players. *Orthopaedic Journal of Sports Medicine*, *6*(1). https://doi.org/10.1177/2325967117750825

Beischer, S., Gustavsson, L., Senorski, E. H., Karlsson, J., Thomeé, C., Samuelsson, K., & Thomeé, R. (2020). Young athletes who return to sport before 9 months after anterior cruciate ligament reconstruction have a rate of new injury 7 times that of those who delay return. *Journal of Orthopaedic and Sports Physical Therapy*, *50*(2), 83–90. https://doi.org/10.2519/jospt.2020.9071

Chan, D. K. C., Lee, A. S. Y., Hagger, M. S., Mok, K. M., & Yung, P. S. H. (2017). Social psychological aspects of ACL injury prevention and rehabilitation: An integrated model for behavioral adherence. In *Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology* (Vol. 10, pp. 17–20). Elsevier (Singapore) Pte Ltd. https://doi.org/10.1016/j.asmart.2017.10.001

Cho, W., Barradas, V. R., Schweighofer, N., & Koike, Y. (2022). Design of an Isometric End-Point Force Control Task for Electromyography Normalization and Muscle Synergy Extraction From the Upper Limb Without Maximum Voluntary Contraction. *Frontiers in Human Neuroscience*, *16*. https://doi.org/10.3389/fnhum.2022.805452

Coombs, R., & Garbutt, G. (2002). Review article developments in the use of the hamstring/ quadriceps ratio for the assessment of muscle balance. In © *Journal of Sports Science and Medicine* (Vol. 1). http://www.jssm.org

Croisier, J. L., Ganteaume, S., Binet, J., Genty, M., & Ferret, J. M. (2008). Strength imbalances and prevention of hamstring injury in professional soccer players: A prospective study. *American Journal of Sports Medicine*, *36*(8), 1469–1475. https://doi.org/10.1177/0363546508316764

Domaradzki, J., & Koźlenia, D. (2022). The performance of body mass component indices in detecting risk of musculoskeletal injuries in physically active young men and women. *PeerJ*, *10*. https://doi.org/10.7717/peerj.12745

Duan, L. (2021). Empirical analysis on the reduction of sports injury by functional movement screening method under biological image data. *Revista Brasileira de Medicina Do Esporte*, *27*(4), 400–404. https://doi.org/10.1590/1517-8692202127042021_0110

Emery, C. A., & Pasanen, K. (2019). Current trends in sport injury prevention. In *Best Practice and Research: Clinical Rheumatology* (Vol. 33, Issue 1, pp. 3–15). Bailliere Tindall Ltd. https://doi.org/10.1016/j.berh.2019.02.009

Fernandes, T. L., Felix, E. C. R., Bessa, F., Luna, N. M., Sugimoto, D., Greve, J. M. D., & Hernandez, A. J. (2016). Evaluation of static and dynamic balance in athletes with anterior cruciate ligament injury – A controlled study. *Clinics*, *71*(8), 425–429. https://doi.org/10.6061/clinics/2016(08)03

Hewett, T. E., Zazulak, B. T., Myer, G. D., & Ford, K. R. (2005). A review of electromyographic activation levels, timing differences, and increased anterior cruciate ligament injury incidence in female athletes. In *British Journal of Sports Medicine* (Vol. 39, Issue 6, pp. 347–350). https://doi.org/10.1136/bjsm.2005.018572

Kellis, E., Sahinis, C., & Baltzopoulos, V. (2022). Is hamstrings-to-quadriceps torque ratio useful for predicting anterior cruciate ligament and hamstring injuries? A systematic and critical review. In *Journal of Sport and Health Science*. Elsevier B.V. https://doi.org/10.1016/j.jshs.2022.01.002

Kim, D., & Hong, J. (2011). Hamstring to quadriceps strength ratio and noncontact leg injuries: A prospective study during one season. *Isokinetics and Exercise Science*, *19*(1), 1–6. https://doi.org/10.3233/IES-2011-0406

Kyle, U. G., Bosaeus, I., De Lorenzo, A. D., Deurenberg, P., Elia, M., Gómez, J. M., Heitmann, B. L., Kent-Smith, L., Melchior, J. C., Pirlich, M., Scharfetter, H., Schols, A. M. W. J., & Pichard, C. (2004). Bioelectrical impedance analysis - Part II: Utilization in clinical practice. *Clinical Nutrition*, *23*(6), 1430–1453. https://doi.org/10.1016/j.clnu.2004.09.012

Lee, J. H., Kim, S., Heo, J., Park, D. H., & Chang, E. (2022). Differences in the muscle activities of the quadriceps femoris and hamstrings while performing various squat exercises. *BMC Sports Science, Medicine and Rehabilitation*, *14*(1). https://doi.org/10.1186/s13102-022-00404-6

Munthe, R. V., Hendrika, W., & Gurusinga, N. Y. (2021). Relationship between Body Mass Index (BMI) and Knee Osteoarthritis at the UKI General Hospital, Jakarta in 2017. *International Journal of Health Sciences and Research*, *11*(10), 365–377. https://doi.org/10.52403/ijhsr.20211047

Myer, G. D., Ford, K. R., Barber Foss, K. D., Liu, C., Nick, T. G., & Hewett, T. E. (2009). The relationship of hamstrings and quadriceps strength to anterior

cruciate ligament injury in female athletes. *Clinical Journal of Sport Medicine*, *19*(1), 3–8. https://doi.org/10.1097/JSM.0b013e318190bddb

Navacchia, A., Ueno, R., Ford, K. R., DiCesare, C. A., Myer, G. D., & Hewett, T. E. (2019). EMG-Informed Musculoskeletal Modeling to Estimate Realistic Knee Anterior Shear Force During Drop Vertical Jump in Female Athletes. *Annals of Biomedical Engineering*, *47*(12), 2416–2430. https://doi.org/10.1007/s10439-019-02318-w

O'donnell, S. R., Eitan, D. N., & Roper, J. L. (2020). A Comparison of Quadriceps-to-Hamstrings Ratios During Isokinetic Testing, Cutting, and Drop Landings in Male Soccer Players. In *International Journal of Exercise Science* (Vol. 13, Issue 4). http://www.intjexersci.com

Pelana, R., Hanif. A. S., & Saleh. C. I. (2020). *Teknik Dasar Bermian Olahraga Petanque*. PT Raja Grafindo Persada: Depok.

Pelana, R., Setiakarnawijaya, Y., Dwiyana, F., Sari, L. P., Abdurrahman, Antoni, R., & Yusmawati. (2021). The effect of arm length, arm endurance and self-confidence on petanque shooting. *Journal of Physical Education and Sport*, *21*, 2381–2388. https://doi.org/10.7752/jpes.2021.s4319

Perkins, S., & Canavan, P. (2023). Isokinetic Assessment of Knee Flexor and Extensor Strength and Lower Extremity Flexibility Assessment of an NCAA Division III Men's Soccer Team. *International Journal of Sports Physical Therapy*, *V18*(3). https://doi.org/10.26603/001c.74971

Prieto-González, P., Martínez-Castillo, J. L., Fernández-Galván, L. M., Casado, A., Soporki, S., & Sánchez-Infante, J. (2021). Epidemiology of sports-related injuries and associated risk factors in adolescent athletes: An injury surveillance. *International Journal of Environmental Research and Public Health*, *18*(9). https://doi.org/10.3390/ijerph18094857

Richmond, S. A., Nettel-Aguirre, A., Doyle-Baker, P. K., Macpherson, A., & Emery, C. A. (2016). Examining Measures of Weight as Risk Factors for Sport-Related Injury in Adolescents. *Journal of Sports Medicine*, *2016*, 1–5. https://doi.org/10.1155/2016/7316947

Ristolainen, L., Kettunen, J. A., Kujala, U. M., & Heinonen, A. (2012). Sport injuries as the main cause of sport career termination among Finnish top-level athletes. *European Journal of Sport Science*, *12*(3), 274–282. https://doi.org/10.1080/17461391.2011.566365

Ruas, C. V, Brown, L. E., Lima, C. D., Costa, P. B., & Pinto, R. S. (2018). *Effect of three different muscle action training protocols on knee strength ratios and performance*. https://doi.org/10.1519/JSC.0000000000002134

Ruas, C. V., Pinto, R. S., Haff, G. G., Lima, C. D., Pinto, M. D., & Brown, L. E. (2019). Alternative Methods of Determining Hamstrings-to-Quadriceps Ratios: a Comprehensive Review. In *Sports Medicine - Open* (Vol. 5, Issue 1). Springer. https://doi.org/10.1186/s40798-019-0185-0

Ryman Augustsson, S., & Ageberg, E. (2017). Weaker lower extremity muscle strength predicts traumatic knee injury in youth female but not male athletes. *Exerc Med*, *3*, 222. https://doi.org/10.1136/bmjsem-2017

Schweizer, N., Strutzenberger, G., Franchi, M. V., Farshad, M., Scherr, J., & Spörri, J. (2022). Screening Tests for Assessing Athletes at Risk of ACL Injury or Reinjury—A Scoping Review. In *International Journal of Environmental*

Research and Public Health (Vol. 19, Issue 5). MDPI. https://doi.org/10.3390/ijerph19052864

Sytema, R., Dekker, R., Dijkstra, P. U., Ten Duis, H. J., & Van Der Sluis, C. K. (2010). *Upper Extremity Sports Injury: Risk Factors in Comparison to Lower Extremity Injury in More Than 25 000 Cases*. www.cjsportmed.com

Vaienti, E., Scita, G., Ceccarelli, F., & Pogliacomi, F. (2017). *Understanding the human knee and its relationship to total knee replacement*. https://doi.org/10.23750/abm.v88i2

Wang, Y., Li, F., Liu, H., Zhang, Z., Wang, D., Chen, S., Wang, C., & Lan, J. (2022). Robust muscle force prediction using NMFSEMD denoising and FOS identification. *PLoS ONE*, *17*(8 August). https://doi.org/10.1371/journal.pone.0272118

Yuliana, E., & Kushartanti, D. W. (2020). Knee functional and psychological readiness of post ACL injury in operative and non-operative treatment. *Jurnal Penelitian Pembelajaran*, *6*(3), 561–574. https://doi.org/10.29407/js_unpgri.v6i3.14626

Zaffagnini, S., Grassi, A., Serra, M., & Marcacci, M. (2015). Return to sport after ACL reconstruction: how, when and why? A narrative review of current evidence. *Joints*, *3*(1), 25–30.

Zebis, M. K., Andersen, L. L., Bencke, J., Kjær, M., & Aagaard, P. (2009). Identification of athletes at future risk of anterior cruciate ligament ruptures by neuromuscular screening. *American Journal of Sports Medicine*, *37*(10), 1967–1973. https://doi.org/10.1177/0363546509335000