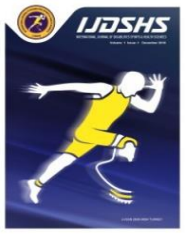

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RESEARCH ARTICLE

Analysis of Step Length and Walking Speed in the Students with History of Ankle Injury: Walking Performance

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Abstract
The purpose of this study was to determine the analysis of stride length and walking speed in the walking gait of students who have ankle injuries. This study is analytical descriptive research with a one-shot case study design. The analysis through video recording of walking gait at 3 meters distance is analyzed using Kinovea software version 0.9.5. The total sample in this study used 27 people from students majoring in Elite Sports at Universitas Negeri Semarang who had an average age of 20 years and had historical injury by the physiotherapy data. This study's results indicated a significant difference between the stride length of people with a history of ankle injury and normal people. It was found that the results of the length of steps and the walking speed of students with a history of ankle injury averaged 1.22 m shorter than normal, which is 1.73 m in stride length. The data found the average speed was 1.135 (m/s) faster than ordinary people who get 1.59 m/s. Limitations in this study are only kinematic data was analyzed and need more kinetics data to complement the founding of this study. Further research is expected to be able to analyze walking gait at each angle in the leg segment which has contributed to improving walking performance.

Keywords
Motion Analysis, Walking Gait, Ankle Injury, Performance

INTRODUCTION

Walking is a physical activity that is very often done by humans every day, because walking is a way of moving for humans (Chumanov et al., 2008). Walking is incorporated into a sports activity because walking can increase the strength of the body's physical fitness. Walking sports have a high interest in Indonesia, because compared to other sports, the level of physical activity of walking can be done by all people. According to Lulic et al., (2010) walking is a simple sport that does not require special training like other sports. In walking, although it looks simply, it involves complex movement mechanisms. Walking requires balance and several physical elements such as height, weight, and physical condition of the body. Balance while walking is the result of dynamic balance in the form of a combination of sagittal, frontal, and transverse planes of the body (Irawan et al., 2023). A person's ability to perform walking activities is influenced by several factors such as gender differences, physical conditions, and the influence of daily activities. From walking, many benefits can be obtained, such as achieving certain goals to making our bodies healthy and fit (Hustinawaty et al., 2012). With one's walking ability can be a reference or benchmark for one's health.

Walking involves two legs to support the balance of the body which starts from one foot touching the ground as a support and propulsion (Baktiyaningsih & Irawan, 2023), and the other leg swings to make one step then repeats until a

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walking motion is created. In a series of walking movements there are two phases, namely the stance phase where the foot is in a position to touch the ground and the swing phase (Liu et al., 2021). Gait analysis is defined as a method used to determine how a person walks (Carlos et al., 2017). According to Arif et al., (2021) gait is a locomotor movement that involves both feet for support and contact with the ground. Mechanical gait requires the cooperation of the upper and lower extremities, indicated by when the feet take turns stepping, the arms and body help to move forward because basically balance is the main factor in the formation of walking motion. Every human being has their own unique walking style (Lulic et al., 2010) that is influenced by several factors, such as height, weight, stride length, physical conditions such as leg length or perhaps due to leg injuries that make a person's gait different from others.

Injury is something that athletes often experience and cannot be avoided Irawan et al., (2021). It is very common to find athletes who experience injuries, both minor and severe injuries. Someone who is injured will experience limitations in movement, due to pain that makes the body move the body not optimally. Injuries experienced by athletes will be very disturbing, both at the time of injury and those who have a history of injury. According to Irawan & Long-ren, (2019) the causes of injuries experienced by humans are different, ranging from body contact, field conditions, muscle weakness or even overuse. One of the injuries that often occurs in sports is ankle sprains, this occurs because the ankle joint is less able to resist medial, lateral, pressure and rotational forces (McGill, 2010). According to Paul & Singh, (2014) humans who walk normally are known for rhythmic and repetitive movements. If a person has a wound or injury to his foot, it will affect the angle of movement and have an abnormal gait and is categorized as alarming (Rohila et al., 2010). For people who have a history of injury to the foot, especially the ankle, will experience interference in walking, so walking gait analysis can be used to support traditional medical diagnoses to determine the cause and also provide recommendations for healing efforts (Siamak et al., 2021).

Sports biomechanics is a science used to study motion produced by living things, especially to improve athlete performance (Prastiwi & Irawan, 2022). Biomechanical analysis in sports will help to prevent injuries and can achieve effective and efficient movements (Irawan & Long-Ren, 2019). According to Irawan et al., (2019) biomechanical analysis is used to analyze movements through images or videos which will then be processed in video analyzer software, one of which is kinovea software. This makes researchers interested in analyzing the length and speed of steps in walking gait for people who have a history of ankle injury.

In connection with previous research, it is suggested that the stride length of taller people will tend to have a longer stride length and higher speed (Siamak et al., 2021). It was found that the stride length of male subjects was 5% lower due to differences in the anthropometry of the subjects taken. The distribution of subject data greatly affects the results of gait parameters. Research on walking gait was presented by (Hagoort et al., 2023), in his research it was found that walking conditions with age will affect the results of walking gait analysis. Different age groups will also affect the balance in walking (Adnindya et al., 2022). Some older people will have a slower walking speed caused by psychological factors. Since it has been verified that the age and walking condition of a person will affect the variability, stability, time, and frequency. The development of health and sports technology today allows analysis of gait (Baker, 2006), this gait analysis is used to find out what disorders affect a person's gait. It is hoped that the solutions provided will be useful in preventing injuries and treating them.

Based on the results of observations made, it was found that at least one out of eight students who had a history of ankle injuries showed a gait that was different from normal students. The gait that is carried out looks less than optimal in the injured area, one of which is the ankle. This can make other parts of the body that are not injured will support 2 times the load to help the movement function of the injured leg. One example occurred in a student with a history of ankle injuries to the legs. People with ankle injuries will apply a limping gait with the aim of reducing the contact of the injured leg in direct contact with the ground (Muro-de-la-herran et al., 2014). Good body position by maintaining body balance and coordinating simultaneous hand and foot movements will make walking comfortable and avoid injury. This made researchers interested in

analyzing walking gait in students who have a history of ankle injuries by focusing on stride length and speed. This study aims to determine the analysis of step length and walking speed in the walking gait of students who have ankle injuries. In addition, the author also hopes that this research can be used as a reference for further research related to walking gait and injury.

MATERIALS AND METHODS

Participants

The method used in this research is quantitative descriptive to find out the kinematic data of walking gait movement with a more detailed description of the information. This descriptive study describes information on stride length and walking speed in students with a history of ankle injury. The sample used in this study was 27 students of Sports Science at Universitas Negeri Semarang, Indonesia who had a history of ankle injuries based on the data and information provided during initial field observations. The average body height 1.66±0.66 meters and weight 58.3±9.95 kg with an average BMI 21.4±3.2 kg/m^2. The instrument in this study uses software that is used to analyze videos in the form of Kinovea Software version 0.9.5 (Irawan, Nomi, et al., 2021). There are several other instruments that support this research, including: 1) Canon 1300D camera with Full HD 1080 x 1920 resolution with a speed of 30 FPS/ Frame Rate Per Second, 2) camera tripod, 3) stationery, 4) informed consent sheet, 5) a blank containing the respondent's personal data and 6) an indicator form for the suitability of the movement analysis. In the data collection stage, the walking gait motion analysis is carried out with the help of a camera and a tripod to record walking movements. The recorded videos were then analyzed using the Kinovea software (Irawan, Nomi, et al., 2021). Setting camera is placed perpendicular to the research sample with a predetermined distance of 3 meters from the camera to the subject (Baktiyaningsih & Irawan, 2023). The sample is given 2 times the opportunity to make walking movements. The indicators studied included elbow angle, leg angle, shoulder angle, stride length, and walking speed. This study followed ethical standards and received approval from the Universitas Negeri Semarangwith reference number (101/KEPK/EC/2023). Participant provided informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

RESULTS

The analysis of walking motion in this study is divided into two phases, they are the stance phase and the swing phase which are presented in Figure 1.

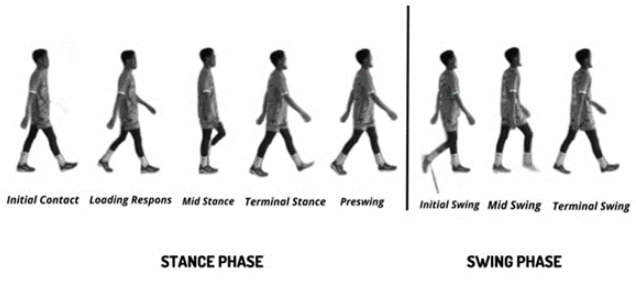

Figure 1. Walking gait phase

The stance phase becomes the dominating phase in the walking gait movement which occupies 60% of the total walking gait phase. In the stepping phase there are several stages such as heel strike, foot flat, midstance, heel off, and toe off. The stance phase begins when the foot is in contact with the ground and starts from the initial contact (heel strike) position with a neutral ankle angle 0°, and hip flexion of 30°. The next movement is followed by the loading response phase, mid stance and preswing. The swing phase accounts for 40% of the total walking phase. The swing phase is marked by the position of the feet that are not touching the ground (Lulic et al., 2010). The following can be kinematic data on walking gait analysis in students with ankle injuries.

Based on table 1 on the results of the walking gait analysis, the average right step speed is 1.14 (m/s) and the average left step speed is 1.13 (m/s). The average step length of the right foot is 1.22 meters, and the average length of the left foot is 1.22 meters. Overall, the average stride length and speed on the left and right feet were not significantly different.

Table 1. Kinematics data

N=27	Mean ± SD	Min	Max
Right Step Speed (s)	1,14 ± 0,13	0,96	1,20
Left Step Speed (s)	1,13 ± 0,10	1,00	1,16
Right Stride Length (m)	1,22 ± 0,11	1,02	1,42
Left Stride Length (m)	1,22 ± 0,10	1,02	1,40

However, this study found that the stride length and speed of the left foot were faster than the right foot. This was found when the sample was running and there was an imbalance between the right and left positions while walking. Lameness can occur due to discomfort in the injured leg so that it speeds up movement to reduce pain.

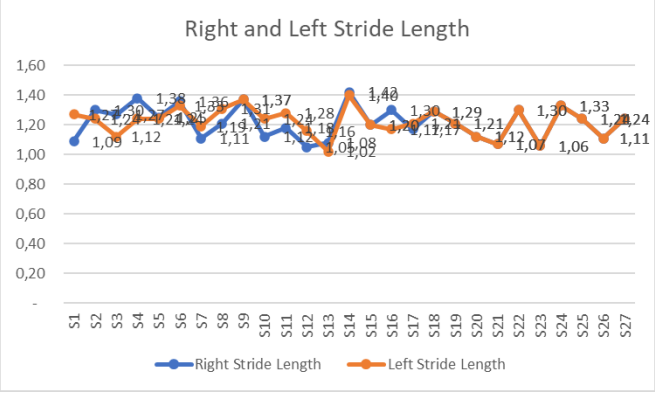

Figure 2. Right and left stride length

Based on Figure 2 below, it was found that students who had a history of ankle injuries showed a difference in length between the right and left steps. The shortest right step is produced by sample number 23, which is 1.02 meters, and the longest right step is produced by sample number 12, which is 1.42 meters. While the shortest left footstep was produced by sample number 13 which was 1.02 meters, and the longest left footstep was produced by sample number 14 which was 1.40 meters.

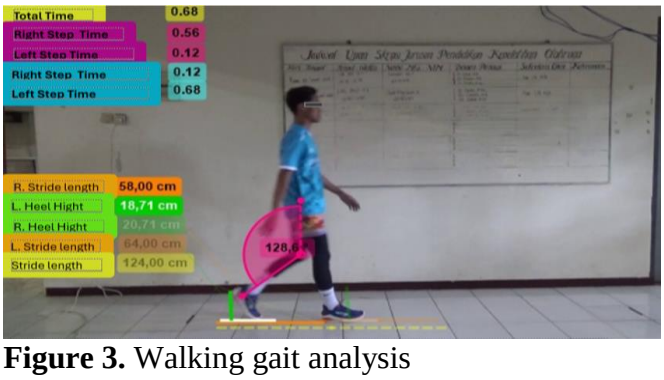

Figure 3. Walking gait analysis

The walking analysis (Figure 3) of the gait cycle is important in the biomechanical mobility examination to gain information about lower limb dysfunction in dynamic movement and loading.

DISCUSSION

Based on Figure 2 below, it was found that students who had a history of ankle injuries showed a difference in length between the right and left steps. The shortest right step is produced by sample number 23, which is 1.02 meters, and the longest right step is produced by sample number 12, which is 1.42 meters. While the shortest left footstep was produced by sample number 13 which was 1.02 meters, and the longest left footstep was produced by sample number 14 which was 1.40 meters.

In normal people, the resulting stride length between the left and right legs is relatively the same (Chumanov et al., 2008; Fukuchi et al., 2019). The difference in stride length that occurs can be caused by limited motion in the injured leg. This is characterized by an imbalance in the legs to reduce pressure on the injured leg, thereby shortening the time during the stance phase (Liu et al., 2021).

Walking is a locomotion movement nvolving two legs, to support propulsion with one foot in contact with the ground. Even though walking looks simply, it involves various mechanisms that can cause complex movements. The walking gait cycle describes the cyclic pattern of movement that occurs while walking. A single cycle of gait starts when the heel of one foot strikes the ground and ends when that same heel touches the ground again. Walking requires the healthy functioning of several body systems including the musculoskeletal, nervous, cardiovascular, and respiratory systems. These systems provide balance, mobility, and stability as well as higher cognitive function and executive control. A loss of healthy gait function can lead to falls, injuries, loss of movement and personal freedom, and a significantly reduced quality of life.

When analyzing the gait cycle, it is best to examine one joint at a time. Objective and subjective methods can be used. According to (Khamis et al., 2021; Siamak et al., 2021), people with chronic ankle injuries tend to walk in an inverted position at the ankle. In fact, during the loading response phase the foot should be balanced

with eversion to relieve shock to the ankle so that there is less chance of the ankle being injured (Baker, 2006).

Differences in stride can also be caused by the response of the hip joint to an injury to the ankle. The response shown is that the hip joint moves more in adduction, which means that movement (Hussein Et Al., 2024; Salih, 2024) in this joint causes the leg to move more dominantly when it approaches the medial side of the body (Liu et al., 2021). The injury causes differences in speed and stride length between the right and left legs. The impact of a history of injury to the leg means that when walking, people will try to endure the pain and shift their body weight to the normal leg. Prevention (Irawan et al., 2022) is better than cure so that the injury does not become worse. There needs to be a correction of gait which can cause and even exacerbate injuries (Ünlü et al., 2024), especially ankle injuries. Using kinesiotaping (Hisham et al., 2017) is a way to help the ankle joint to maximize eversion of the foot at heel strike without limiting inversion at the end of the stepping phase. However, this tool only functions as a supporting tool. To rehabilitate injuries that have occurred, regular therapy and monitoring are still needed and balanced with weight training to strengthen muscles and how to avoid repeated injuries.

Conclusion

The conclusion of this study found that there is a significant difference between the stride length of people who have a history of ankle injury and people who do not have a history of ankle injury or are called normal. The results of stride length and walking speed of students who have a history of ankle injury have an average stride length of 1.22 meters with an average speed of 1.135 (m/s). At the same time, the stride length of ordinary people or those without a history of ankle injury is an average stride length of 1.73 meters with a speed of 1.59 m/s. Student who have an ankle injury will speed up their movement because they must endure the pain of the injury they have. The effect of this injury makes the distance of steps shorter when compared to a normal leg, because in addition to enduring pain it also holds the body's weight on the footstool so that the ability is balanced. The limitations in this study are only discussed in the form of kinematic data. For further research, it is expected to be able to analyze walking gait movements at every angle of specific motion and more detailed movements to improve walking gait performance.

Acknowledgement

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Conflict of Interest

The authors declare no potential conflicts of interest to the research, authorship, and/or publication of this article. ***

Ethics of Research

This study followed ethical standards and received approval from the Universitas Negeri Semarang (Health Research Ethics Committee) in Indonesia with Number 101/KEPK/EC/2023.

Author Contributions

Study Design, FAI, MRA; Data Collection, NR, DFWP; Statistical Analysis, NR, TASP; Data Interpretation, FAI; Manuscript Preparation, FAI, MRA, TASP; Literature Search, KA, DFWP. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Adnindya, M. R., Redha, A. H., Septadina, I. S., Suciati, T., & Wardiansah. (2022). Analisis Hubungan Usia, Indeks Masa Tubuh, Kecepatan Berjalan Dan Riwayat Jatuh Dengan Keseimbangan Berjalan Lansia Majelis Taklim Asmaul Husna Palembang. *Jurnal Kedokteran Dan Kesehatan : Publikasi Ilmiah Fakultas Kedokteran Universitas Sriwijaya*, *9*(2), 191–198. [CrossRef]

Arif, M., Ardha, A., Yang, C. B., Kartiko, D. C., Ferianto, B., Kuntjoro, T., Ristanto, K. O., Wijaya, A., Adhe, K. R., Putra, K. P., Irawan, F. A., Nevangga, R. P., Sasmita, N. S., & Rizki, A. Z. (2021). Biomechanics Analysis of Elementary School Students ' Fundamental Movement Skill (FMS). *International Joint Conference on Arts and Humanities 2021 (IJCAH 2021)*, *618*(Ijcah), pp.471-476.

Baker, R. (2006). Gait Analysis Methods in Rehabilitation. *Journal of NeuroEngineering and Rehabilitation*, *Vol.3*(No.4), pp.1-10. [Pubmed]

Baktiyaningsih, L., & Irawan, F. A. (2023). Analisis Lari 1000 Meter Pada Anak Sekolah Dasar Bina Amal Kota Semarang: Tinjauan Biomekanika Olahraga. *Journal of Sport (Sport, Physical Education, Organization, Recreation, and Training)*, *Vol.7*(No.1), pp.137-142. [CrossRef]

Carlos, A. J., Iván, M. H., & Antonio, C. J. (2017). Analysis of the Kinematic Variation of Human Gait Under Different Walking Conditions Using Computer Vision. *Articulo De Investigacion*, *Vol.38*(No.2), pp.437-457. [CrossRef]

Chumanov, E. S., Wall-scheffler, C., & Heiderscheit, B. C. (2008). Gender Differences in Walking and Running

on Level and Inclined Surfaces. *Clinical Biomechanics*, *Vol. 23*(No.10), pp.1260-1268. [PubMed]

Fukuchi, C. A., Fukuchi, R. K., & Duarte, M. (2019). Effects of walking speed on gait biomechanics in healthy participants : a systematic review and meta-analysis. *Systematic Reviews*, *VOl.8*(No.153), pp.1-11. [Pubmed]

Hagoort, I., Vuillerme, N., Hortobágyi, T., & Lamoth, C. J. C. (2023). Age and walking conditions differently affect domains of gait. *Human Movement Science*, *89*(March). [PubMed]

Hisham, N. A. H., Nazri, A. F. A., Madete, J., Herawati, L., & Mahmud, J. (2017). Measuring Ankle Angle and Analysis of Walking Gait using Kinovea. *International Medical Device and Technology Conference 2017*, pp.247-250.

Hussein, A., Abdzid Ashoor, I., & Saeed Majed, S. (2024). The Effectiveness of a Differentiated Learning Strategy using Flexible Groups to Improve Football Skills and Keep It. *International Journal of Disabilities Sports and Health Sciences*, *vol.7*(no.1), pp.236-244. [CrossRef]

Hustinawaty, Jannah, M., & Rahman, R. F. (2012). Model Berbasis Ekstraksi Untuk Analisis Gaya Berjalan. *Teknologi Informasi Dan Komunikasi (TIK) Untuk Ketahanan Nasional*, pp.12-20. [Crossref]

Irawan, F. A., Hadi, Romadhoni, S., Permana, D. F. W., & Billah, T. R. (2021). Be Fit Bye Fat Sebagai Metode Peningkatan Derajat Kebugaran Jasmani Pegawai Pertamina MOR IV Semarang. *JOSSAE : Journal of Sport Science and Education*, *Vol.6*(No.1), pp.67-73. [CrossRef]

Irawan, F. A., & Long-ren, C. (2019). Baseball and biomechanics : Injury prevention for baseball pitcher. *Jurnal Keolahragaan*, *vol.7*(no.1), pp.57-64. [CrossRef]

Irawan, F. A., Nomi, M. T., & Peng, H. (2021). Pencak Silat Side Kick in Persinas ASAD : Biomechanics Analysis. *International Journal of Human Movement and Sports Sciences*, *Vol.9*(No.6), pp.1230-1235. [CrossRef]

Irawan, F. A., Permana, D. F. W., Akromawati, H. R., & Yang-tian, H. (2019). Biomechanical Analysis of Concentration and Coordination on The Accuracy in Petanque Shooting. *Journal of Physical Education, Sport, Health and Recreations*, *vol.8*(no.2), pp.96-100. [CrossRef]

Irawan, F. A., Permana, D. F. W., Nurrahmad, L., Anam, K., Hadi, Romadhoni, S., & Ghassani, D. S. (2023). A Motion Analysis of Volleyball Open Spike: Kinematics and Performance. *International Journal of Human Movement and Sports Sciences*, *11*(1), 134–142. [CrossRef]

Irawan, F. A., Permana, D. F. W., Solikhun, I. D. B., Anam, K., Fanita, Z. C., & Ghassani, D. S. (2022). Risk Factors of Sitting Cross-Legged on Low Back Pain of Students at Islamic Boarding School. *Hunan Daxue Xuebao/Journal of Hunan University Natural Sciences*, *Vol.49*(No.9), pp.217-222. [CrossRef]

Khamis, S., Gurel, R., Arad, M., & Danino, B. (2021). Identifying Running Deviations in Long Distance Runners Utilizing Gait Profile Analysis : A Case Control Study. *Applied Sciences*, *Vol.11*(No.1), pp1-10. [CrossRef]

Liu, R., Qian, D., Chen, Y., Zou, J., Zheng, S., Bai, B., Lin, Z., Zhang, Y., & Chen, Y. (2021). Investigation of Normal Knees Kinematics in Walking and Running at Different Speeds Using a Portable Motion Analysis System. *Sports Biomechanics*, *Vol.12*, pp.1-14. 1864015 [CrossRef]

Lulic, T. J., Susic, A., & Kodvanj, J. (2010). Biomechanical Analysis of Walking : Effects of gait velocity and arm swing amplitude. *Periodicum Biologorum*, *Vol.112*(No.1), pp.13-17. [CrossRef]

McGill, S. (2010). Core Training: Evidence Translating to Better Performance and Injury Prevention. *Strength and Conditioning Journal*, *Vol.32*(No.3), pp.33-46. [Crossref]

Muro-de-la-herran, A., Garcia-zapirain, B., & Mendez-zorrilla, A. (2014). Gait Analysis Methods: An Overview of Wearable and Non-Wearable Systems, Highlighting Clinical Applications. *Sensors*, *Vol.14*, pp.3362-3394. [PubMed]

Paul, S. N., & Singh, Y. J. (2014). Survey on Video Analysis of Human Walking Motion. *International Journal of Signal Processing, Image Processing and Pattern Recognition*, *Vol.7*(3), pp.99-122.

Prastiwi, T. A. S., & Irawan, F. A. (2022). Tinjauan aspek biomekanika tembakan tiga angka pada permainan bola basket Overview. *Altius: Jurnal Ilmu Olahraga Dan Kesehatan*, *11*(1), 1–10. [CrossRef]

Rohila, N., Kumar, P. B., & Chauhan, N. (2010). Abnormal Gait Recognition. *International Journal on Computer Science and Engineering(ISSN:0975–3397)*, *Vol. 02*(05), 1544–1551.

SALIH, A. fouad. (2024). The Effect of Intermittent and Continuous Instantaneous Strength Training on Biomechanical Ability, Technical Performance and Long Jump Success in Athletics. *International Journal of Disabilities Sports and Health Sciences*, *vol.7*(no.1), pp.168-177. [CrossRef]

Siamak, N., E, C., A, H., & N, A. (2021). Monitoring the Kinematics of Walking and Running Gait After Total Knee Replacement Using a Generation of Kinematic Retaining Prosthetic Knee Implant. *17th International Conference on Condition Monitoring and Assessment Management CM2021*, pp.1-14.

Ünlü, Ç., Çeviker, A., Turgut, A., Kusan, O., Tezcan, E., Gür, K., & Yıldırım, T. (2024). Examination of Mental Stamina and Athlete Injury Anxiety Levels of Wrestlers. *International Journal of Disabilities Sports and Health Sciences*, *vol.7*(no.1), pp.210-222. [CrossRef]