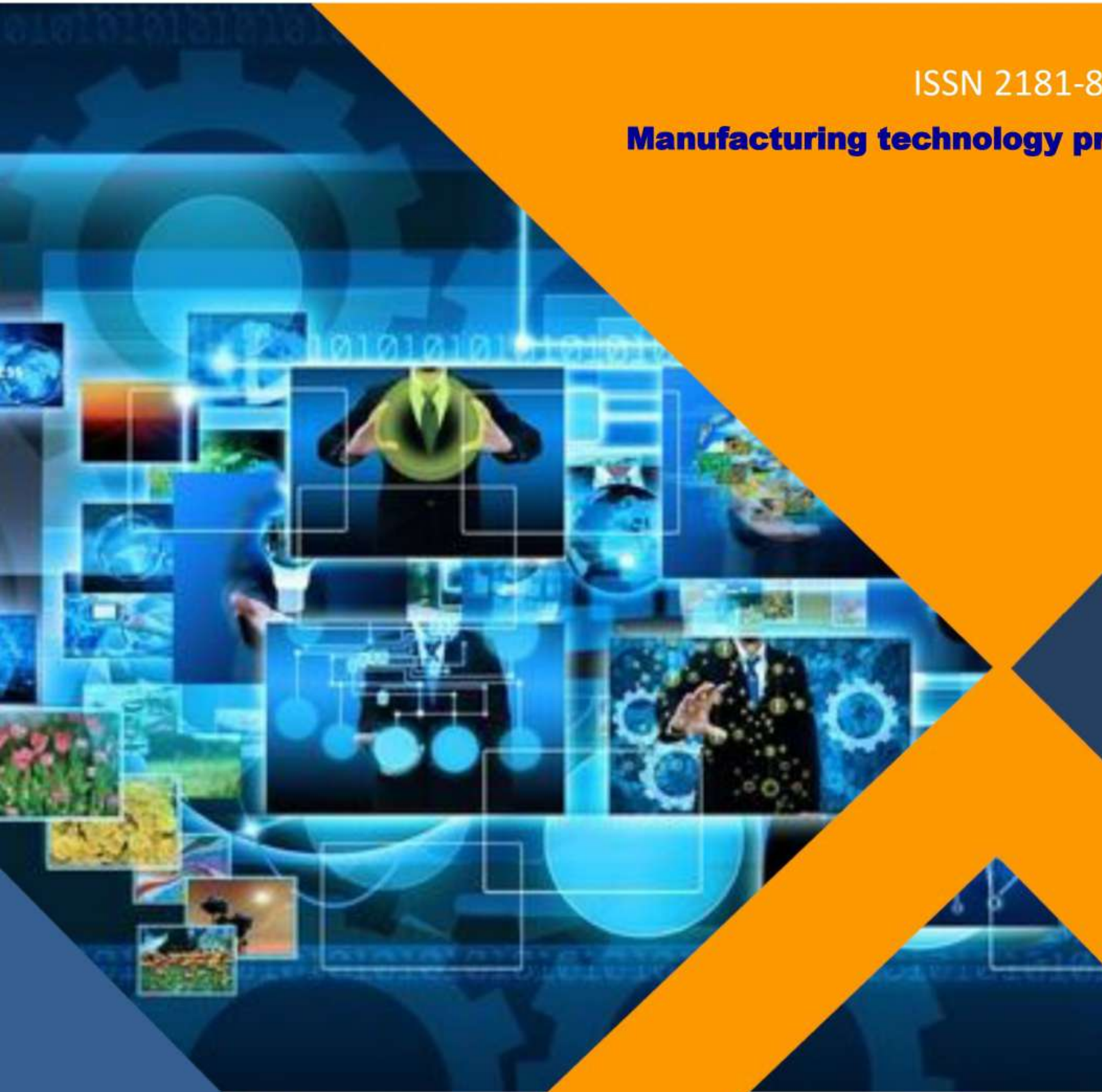


ISSN 2181-8622

Manufacturing technology problems

Scientific and Technical Journal Namangan Institute of Engineering and Technology

INDEX COPERNICUS INTERNATIONAL

Google Scholar

Crossref doi

SLIB.UZ
Scientific library of Uzbekistan

Volume 9
Issue 4
2024

KINEMATICS OF THE FOOT IN A HEALTHY PERSON'S FOOT AND ANKLE INJURY

MUHAMMEDOVA MADINA

Associate Professor at Bukhara Engineering and Technology Institute, Bukhara, Uzbekistan
Phone.: (0890) 512-5070, E-mail.: mukhammedova_92@mail.ru

Abstract: This article presents the results of a phase analysis of foot movement dynamics. Pathological changes in the ankle joint and the causes of their occurrence were also analyzed, and the foot with a pathological condition of the ankle joint was studied. Based on the results of the analysis, the degree of pathology in the ankle joint was determined as a percentage.

Keywords: body weight, ankle joint, fractures, deltoid ligament, immobilization, load, walking cycle, deformation, shock absorption, phase stage, substrate, pronation, supination, orthopedic shoe, rolling.

Introduction. The ankle joint is a movable connection between the foot and the lower leg. On its sides, there are three groups of ligaments that firmly hold the joint in place, which can be easily injured during incorrect jumps, accidental falls, or twisting of the foot. Often, stretching occurs - resulting in microtears of the connective tissue fibers.

The ankle joint is structurally complex and serves as a construction that transfers the supporting load from the body to the foot. It consists of three bones: the tibia, fibula, and talus. Although this joint is not particularly prone to degenerative-dystrophic processes due to its structure, it is vulnerable to incorrect movements that lead to excessive strain on the ligamentous apparatus [1,2]. Stretching of ankle ligaments often occurs when the foot is turned inward, and less frequently when it is turned outward.

The main causes of stretching are:

- incorrect loading of the foot when jumping;
- walking or running on uneven, unstable, or slippery surfaces;
- side impact or sharp pressure on the ankle joint.

Stretching of the foot ligaments is most often observed during the winter season when people accidentally twist their feet while falling on ice or climbing and descending frozen stairs. Additionally, ankle ligaments can be injured during sports activities. Typically, the group of ligaments passing through the outer surface of the joint is affected. The degree of pain in ankle ligament stretching directly depends on the severity of the injury. Proper first aid helps reduce the risk of post-injury complications. The treatment process includes taking pain-relieving and anti-inflammatory medications, immobilizing the joint, and most importantly, using orthopedic footwear to temporarily limit weight-bearing [3,4].

The inflammatory phase lasts up to 2 weeks, while the recovery phase lasts from 1 to 3 months after the injury. Elasticity is fully restored within six months. During this time, the patient may experience symptoms of joint damage (pain, limited movement).

Three groups of ligaments are distinguished in the ankle joint area:

- the joint is secured externally by the calcaneofibular and talofibular ligaments, which have anterior and posterior parts;

• on the inner surface, the deltoid ligament is located, which has deep and superficial layers;

• the tibiofibular ligament connects the tibia and fibula.

The lateral ligament is most commonly injured. The second most frequent injury is to the right or left deltoid ligament. The third most common injury is usually syndesmosis damage between the bones of the lower leg. Other structures are injured much less frequently. The symptoms of this condition include pain, swelling and diffuse bruising of the tissues, limping, or complete restriction of movement in the injured limb [5,6].

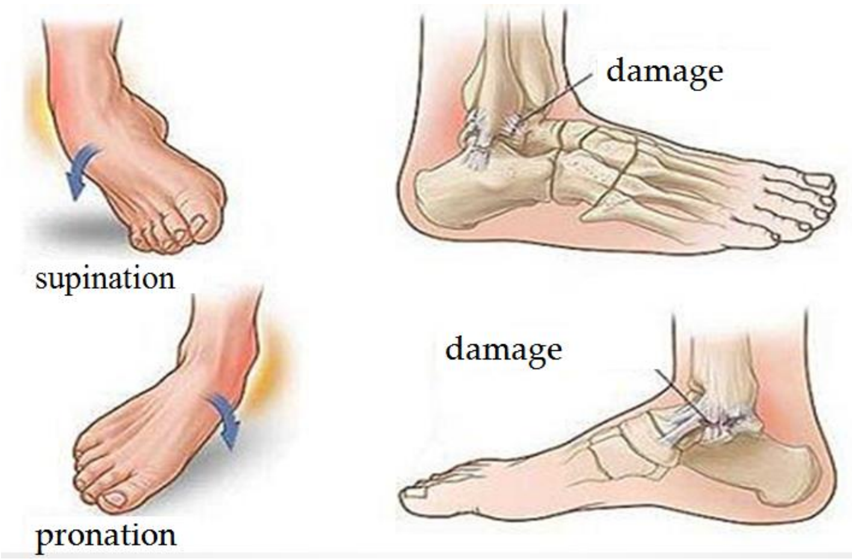


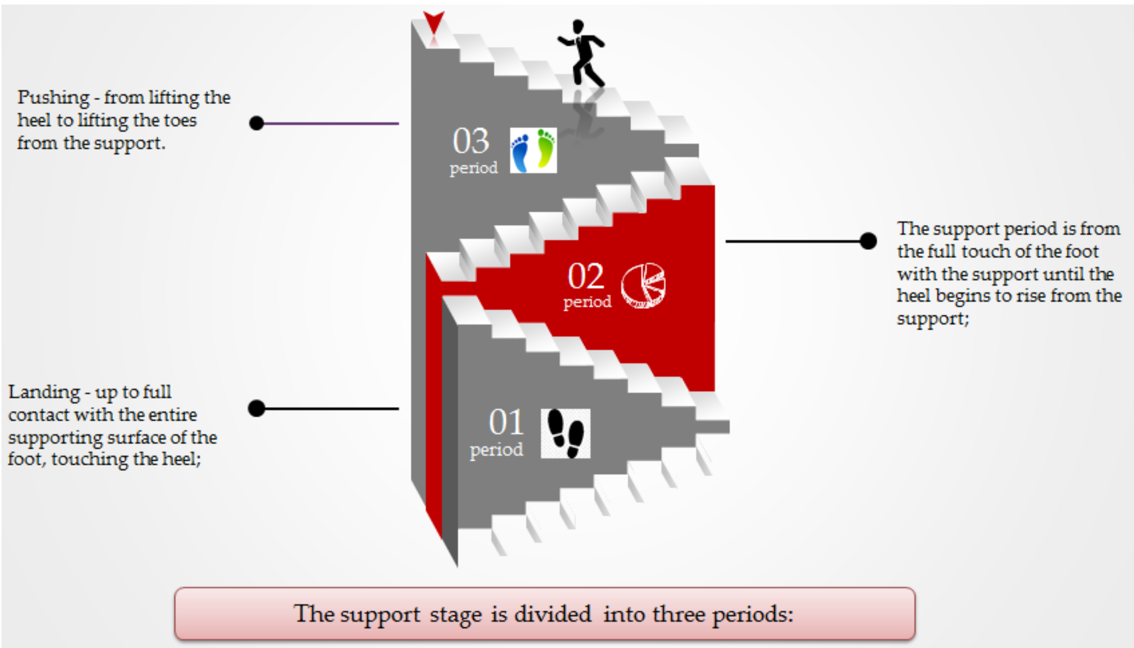
Figure 1. Types of foot injuries based on flexion

An ankle injury occurs when there is an indirect physical impact of small force on the soft tissues of the ankle joint. In this case, a hematoma develops as a result of minor ruptures of muscle fibers and bleeding into the intertissue space. Consequently, the tissues around the joint become swollen, touching the joint is extremely painful, and the range of active movements in the joint slightly decreases due to lower leg pain (Fig. 1).

Stretching of the ankle joint ligaments can occur during irregular movements that cause the ankle joint to flex or twist again. This condition is abnormal for the joint and leads to excessive stretching of the ankle ligament apparatus. The ligaments may stretch or tear. There is also swelling of the soft tissues around the joint, and a hematoma may form at the site of stretching. Occasionally, a plaster cast using the "boot" technique may be applied to completely immobilize the joint and prevent physical strain for additional immobilization. If timely or complete care is not provided to the patient with ligament stretching, this can lead to chronic instability of the ankle joint. Typical dislocations are the result of chronic rupture of the ankle joint apparatus. Foot dislocation is considered complex and extremely painful. During trauma, by rotating the foot inward or outward, the joint surfaces of the ankle lose their alignment, and a dislocation occurs in the joint. The typical presentation for dislocation is foot-ankle deformity, inability to perform active joint movements, and attempts to perform passive movements are very painful [7,8].

Methodology & empirical analysis. Foot dynamics arise from the interaction of forces acting on the foot, and dynamic analysis of the foot is an important orthopedic skill. This represents a dynamic addition to static examination. Biomechanical criteria for walking include variable leg activity, alternating pushing and swinging of each leg. These movements are characterized by strict coordination and conformity to body structure. During the stages of movement, each foot alternately performs the functions of support and transfer. The support period includes phases of shock absorption and push-off, while the transfer period involves phases of leg lifting and deceleration.

When we talk about walking phases, we refer to the entire range of human movements during forward progression. A complete basic cycle consists of two independent stages: stance and swing.



At the beginning of the walking cycle, a person places their foot on the supporting surface, with the maximum load falling on the outer upper part of the heel area. Then, a rolling phase occurs along the outer part of the foot, distributing the load across the entire surface of the foot and providing shock absorption. In the next moment, the maximum load falls on the joints as the person prepares to lift their foot from the support, and the toes are lowered.

Figure 2 above shows a walking cycle starting with the right foot and ending when the left foot touches the ground. The initial heel contact is represented as 0%, the left heel contact time as 50%, and the right heel contact time again as 100% of the walking cycle. The period when the foot is in contact with the ground is called the stance phase, while the period when the foot is off the ground is called the swing phase. The ratio of the stance phase to the swing phase is approximately 6:4, and the proportion of swing phases increases as walking speed increases [9,10].

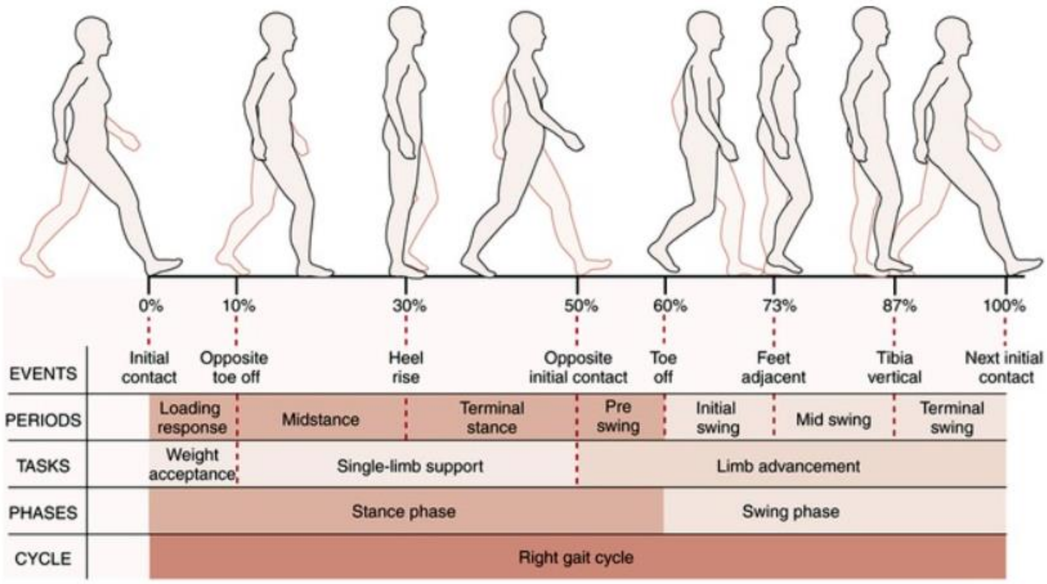
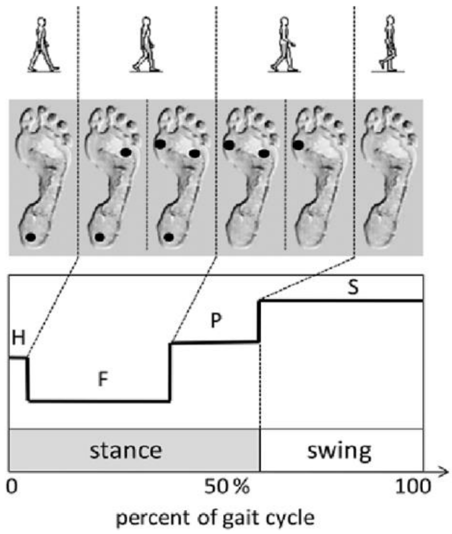
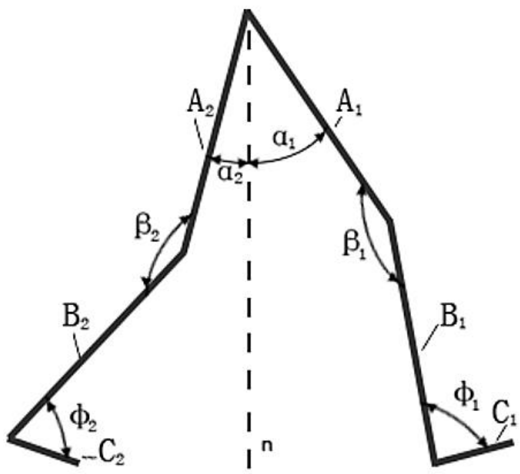


Figure 2. The beginning and end state of the walking cycle

II. Results. The walking cycle represents the step length. In other words, it is the distance from the right heel to the right heel when taking the next step with the right foot. On the other hand, the distance from the right heel to the left heel is considered the stride length. Additionally, the vertical distance between the centralized extension lines on the left and right feet is called the step width. Each person has a different walking cycle, depending on their physical characteristics such as height and leg length [8,9].



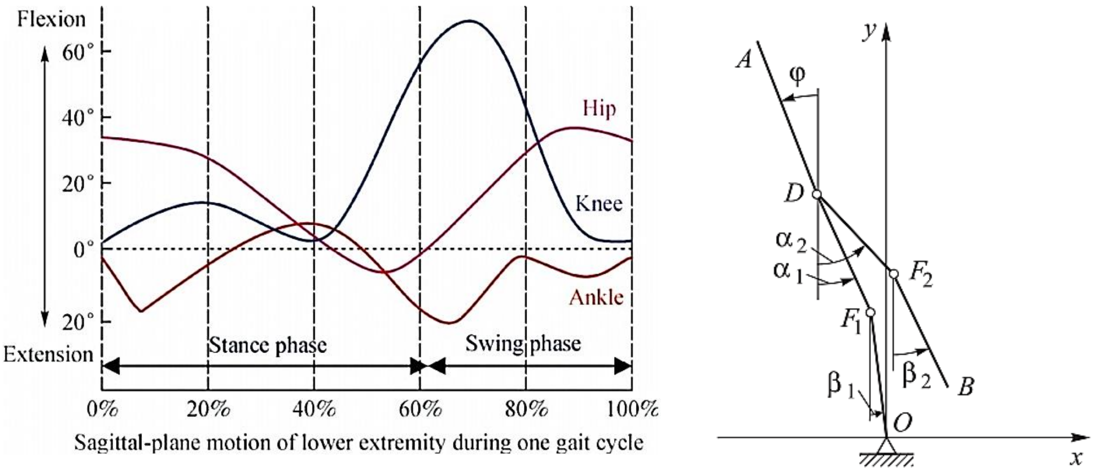
A)



B)

Figure 3. A) The percentage of contact and oscillation phases during walking B) Anthropomorphic six-joint mechanism

Accurate determination of walking phases is important for evaluating kinematic data. Focusing on the foot, each gait cycle is typically divided into two periods, commonly called stance and swing. Stance refers to the entire period when the foot is on the ground, while swing refers to the time when the foot is in the air to move it forward. During normal walking, most gait cycles consist of a sequence of the following three sub-phases: heel contact (H), heel and 5th metatarsal contact (F), metatarsal contact and heel rise (P), followed by foot swing (S) [10]. Pathological changes in the foot can also be detected by evaluating the human gait cycle.



A) B)

Figure 4. A) Movement of the foot in the sagittal plane during the gait cycle B) Kinematic diagram of a flat five-link anthropomorphic mechanism

In the process of walking, two phases can be distinguished - single support and double support phases. According to the data presented, a person never loses their point of support during walking. This is a characteristic feature of this type of movement. Within the framework of the study, it is considered that the single support phase occupies the longest time of the step, while the double support phase occupies the shortest time interval.

In the calculation scheme (Fig. 3 A), the human support leg is indicated by the index "1," while the swing leg is indicated by the index "2." In this model, the links have weight and are in a static state. The links A, B, and C represent the thigh, lower leg, and foot, respectively. The position of the mechanism in the sagittal plane can be represented by 6 angular coordinates - 2 absolute and 4 relative coordinates. The positive direction of the angles is counterclockwise. Undoubtedly, walking is a relatively symmetrical movement in time. Based on this, we conclude the following about the time-dependent angular functions:

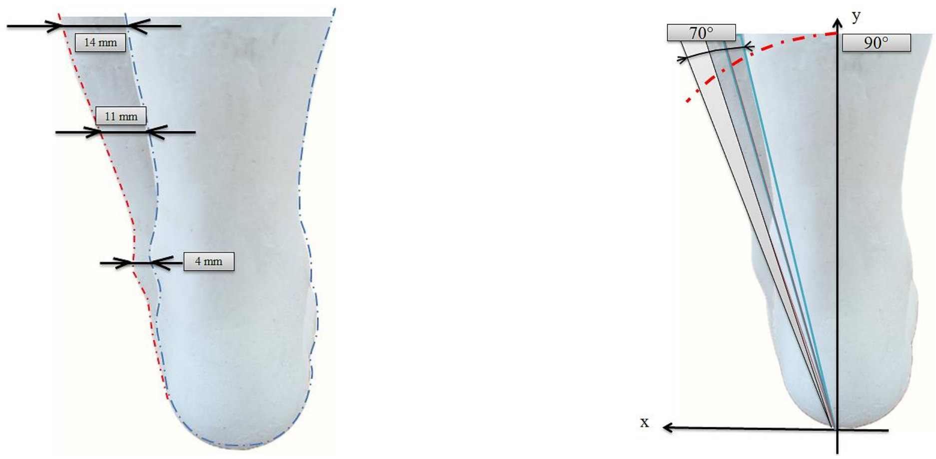
$$\alpha 1\ (0) = \alpha 2\ (T)$$
$$\beta 1\ (0) = \beta 2\ (T)$$
$$\varphi 1\ (0) = \varphi 2\ (T)\ (1)$$

Here, the time point 0 is the beginning of the step, and the time point T is the end of the step. At time T, the support leg becomes the swing leg, and the swing leg becomes the support leg. At the stage of studying kinematics, the laws of angle changes over time, as well as mathematically, this problem has an infinite number of solutions, so experimental data is of great importance.

A flat five-link anthropomorphic mechanism is considered as a mechanical model of a walking human (Fig. 4b). The mechanism consists of five links - the AD body and two identical two-link legs. Each leg consists of the thigh (DF1 on the supporting leg and DF2 on the raised leg) and the lower leg (OF1 on the supporting leg and BF2 on the raised leg). The links of the mechanism are connected to each other by hinges (joints). The knee (at points F1 and F2), hip (at point D) and ankle (at points O and B) joints are considered to be uniaxial hinges with axes perpendicular to the longitudinal (sagittal) plane - the plane of the drawing. Since friction in human joints is low, we consider the mechanism's hinges to be ideal, disregarding friction.

Considering that the double support phase of the step does not exceed 20% of its total execution time, the step is reduced to a single support phase. In this phase, the ankle joint of one of the legs (support) always rests on the support. The movement of the mechanism in the frontal plane is neglected, as the deviation of the center of gravity of the human body in the frontal plane during walking reaches only 2.5 centimeters (when the person is 1.75-2.0 meters tall, the body deviates only 1-2 degrees). Thus, a single support step of a five-link anthropomorphic mechanism with five degrees of freedom in motion in the sagittal plane is considered (in this case, the support leg remains stationary).

III. Conclusions. If we analyze the function of the walking cycle with respect to the angles of the hip, knee, and ankle joints, it can be seen that the knee flexion during the transition from the stance phase to the swing phase is approximately 60 degrees or more.



A) B)

Figure 5. A) Intermediate measurements of the pronation injury angle in the foot; B) Intermediate degrees of the pronation injury angle in the foot

Also, conversely, when examining patients' walking styles, the hip joint, not the knee joint, is most often bent, or the patient walks with their entire leg extended and the pelvis raised.

Because the patient has to bear the entire weight of their leg, they expend more energy while walking, resulting in inefficient gait. Therefore, as shown in the graph above, it is possible to correct the patient's abnormal movements and muscle usage if the sequence of joint movement, muscle utilization, and muscle mobilization during walking is properly applied.

If we analyze the angles of the hip, knee, and ankle joints as a function of the walking cycle, we can see that the knee flexion during the transition from the stance phase to the swing phase is approximately 60 degrees or more. Conversely, when examining patients' gait patterns, it is observed that the hip joint, not the knee joint, bends the most, or the patient walks with their entire leg extended and the pelvis raised.

Since the foot bears the patient's entire weight, it consumes more energy during walking, resulting in inefficient gait. Therefore, as shown in the graph above, it is possible to correct the patient's abnormal movements and muscle usage if the sequence of joint movement, muscle utilization, and muscle mobilization during walking is properly applied.

REFERENCES:

1. Mazanik L.Yu. Influence of the effect of thermodynamic feedback on the thermographic parameters of the foot in vascular diseases of the lower extremities // Biomechanics of the foot of a person // Materials of the International Scientific and Practical Conference (18 - 19 June 2008).
2. Stella I. Money. Sunday A. Afolalu. Joseph F. Kayode. Sunday L. L. Moses E. Emetere. Optimization and Analysis of Female Foot Anthropometry// E3S Web of Conferences 391, 01051 2023). ICMED-ICMPC 2023
3. Dominic J. F., Jonathon B., Luke K. Foot stiffening during the push-off phase of human walking is linked to active muscle contraction, and not the windlass mechanism//Electronic supplementary material is available online at https://doi.org/10.6084/m9.figshare.c.5054614.
4. Erdemir A, Hamel JSC, Fauth AR, Piazza SJ, Sharkey NA. 2004 Dynamic loading of the plantar aponeurosis in walking. J. Bone Joint Surg. 86-A, 546-552.
5. Farris DJ, Kelly LA, Cresswell AG, Lichtwark GA. 2019The functional importance of human foot muscles for bipedal locomotion. Proc. Natl Acad. Sci. USA116, 1645-1650. doi:10.1073/pnas.1812820116)
6. Riddick R, Farris DJ, Kelly LA. 2019 The foot is more than a spring: human foot muscles perform work to adapt to the energetic requirements of locomotion. J. R. Soc. Interface 16, 20180680. (doi:10.1098/rsif. 2018.0680)
7. Carlson RE, Fleming LL, Hutton WC. 2000 The biomechanical relationship between the tendoachilles, plantar fascia and metatarsophalangeal joint dorsiflexion angle. Foot Ankle Int. 21, 18-25. (doi:10.1177/107110070002100104)

8. O. V. Konnov, O. Yu. Alyoshkina, V. N. Nikolenko. Changes in the morphometric parameters of the foot in different forms of the lower extremities // Saratovsky Scientific-Medical Journal 2014; 10 (4): 600-603.

9. Mandrikov VB, Krauhskin AI, Perepelkin AI, et al. Somatotipologiceskie patterns of human foot morphology. Volgograd scientific and medical journal 2013; (2): 5-8. Russian (Mandrikov, B., Krayushkin A. I., Perepelkin A. I. et al. Somatotypological patterns of human foot morphology. Volgograd Scientific Medical Journal 2013; (1): 5-8).

10. Mukhammedova M.O. Scientific-practical analysis of the types and statistics of injuries in the ankle-heel joint// Journal of Engineering and Technology (JET) Received: Aug 23, 2024; Published: Sept 23, 2024 y. – PP. 58-61.

C O N T E N T S

PRIMARY PROCESSING OF COTTON, TEXTILE AND LIGHT INDUSTRY

GROWING, STORAGE, PROCESSING AND AGRICULTURAL PRODUCTS AND FOOD TECHNOLOGIES

CHEMICAL TECHNOLOGIES