**NATIONAL SPORTS ACADEMY**
**"VASSIL LEVSKI" SOFIA**

**FACULTY OF "PUBLIC HEALTH, HEALTH CARE AND TOURISM"**
**DEPARTMENT OF "THEORY AND METHODOLOGY OF KINESITHERAPY"**

## ATANAS KOSTADINOV DRUMEV

**AUTOREFERAT**

**of a**
**dissertation**
**for the award of the Educational and Scientific Degree "Doctor"**
**Doctoral program "Kinesitherapy"**
**Professional field 7.4. "Public Health"**

# RESEARCH ON LOCOMOTOR RECOVERY AFTER TRAUMATIC CONDITIONS OF THE LOWER LIMB

**Scientific advisor:**
**Assoc. Prof. Danelina Emilova Vacheva, Ph.D.**

**Reviewers:**
**Prof. Evgeniya Borisova Dimitrova, Ph.D.**
**Prof. Ruska Vasileva Paskaleva, Ph.D.**

**Sofia, 2025**

## TABLE OF CONTENTS



## LIST OF ABBREVIATIONS

| | |
|---|---|
| **ACL** | Anterior Cruciate Ligament |
| **ADL** | Activities of Daily Living |
| **AFC** | Ankle-Foot Complex |
| **COM** | Center of Mass |
| **CPRM** | Clinic of Physical and Rehabilitation Medicine |
| **CRPS** | Complex Regional Pain Syndrome |
| **DCC** | Diagnostic and Consultation Center |
| **HJ** | Hip Joint |
| **KJ** | Knee Joint |
| **MO** | Metal Osteosynthesis |
| **NHIF** | National Health Insurance Fund |
| **PIR** | Post-Isometric Relaxation |
| **RTA** | Road Traffic Accident |
| **SI** | Symmetry Index |
| **SP** | Stance Phase |
| **SS** | Single Support |
| **SW** | Swing Phase |
| **UMHAT** | University Multiprofile Hospital for Active Treatment |
| **VAS** | Visual Analog Scale for Pain |
| **WHO** | World Health Organization |

## INTRODUCTION

The ability of living organisms to move through the environment is essential for their survival. In scientific literature, this ability is known as locomotion, with various forms being recognized. In humans, the primary mode of locomotion in the environment is walking, which is a natural motor act that allows the human body to move through the environmental surface. Walking is a fundamental part of daily life, enabling individuals to move from one place to another through coordinated and purposeful movements. This process is extremely complex and requires precise interaction between various organs and systems—musculoskeletal, nervous, and cardiovascular. They work in harmony to ensure stability, efficiency, and adaptability of movements. Walking is characterized by its rhythmic and cyclical nature, which maintains balance and stability during movement, while requiring minimal energy expenditure. It is a motor habit that is highly automated, strictly individual, and non-strenuous, with muscle contractions being extremely economical. Climbing and descending stairs is also a common locomotor activity in modern humans. Again, there is a cyclical execution of the swing and stance phases with counteracting, neutralizing movements of the upper limbs and shoulder girdle. The normal walking pattern is typically achieved by the age of 7, but in older adults, this motor habit, built up over the years, can "break down" within a few days.

As a result of trauma, an individual's mobility is limited, and their ability to perform self-care activities is impaired. This leads to a reduction in their work capacity and difficulty in social functioning. The available literature provides detailed descriptions of all the key spatial and temporal characteristics of gait in healthy individuals, as well as the methods and techniques for their recording. Numerous studies have been conducted on large groups of people to establish average norms for individual gait characteristics. The kinesiological basis of the cyclical nature of normal walking is well-known, along with the corresponding pathokinesiological knowledge for various lower limb injuries and diseases, which result in pathological gaits. Modern scientific and practical developments reflect the latest achievements in science, technology, and practice, enabling their integration into clinical studies to analyze the data they provide and apply it in everyday clinical practice.

Our interest in the possibility of independent movement in space is driven by the frequency of lower limb injuries and the significant number of patients who require assistive devices to aid and facilitate walking. Practice in the field of medical rehabilitation shows that when independent walking becomes impossible due to injury or disease of the lower limbs, patients become immobilized, their social contacts are limited, and their quality of life deteriorates. All of this has drawn our attention to conducting this scientific study and analyzing the results obtained for the recovery of gait parameters in various post-traumatic conditions that disrupt normal walking.

The **AIM** of this study is to investigate, monitor and evaluate the recovery of gait parameters and locomotor activity in patients with post-traumatic conditions of the lower limb.

**OBJECTIVES of the study**

1. To review the gait parameters in the available scientific literature and systematize the pathokinesiological features of the most common lower limb injuries in clinical practice.
2. To explore different technological devices and select the most appropriate one with the corresponding software for assessing gait asymmetry, while developing an appropriate research methodology.
3. To define criteria for selecting patients suitable for inclusion in the study based on age, gender, injury localization, and the traumatic-orthopedic therapeutic (surgical) approach, and to conduct initial and final measurements, which will be documented in the patient's Individual file.
4. To perform a comparative analysis of the results regarding the recovery of gait parameters, activities of daily living (ADLs), and locomotor activity within different groups.
5. To formulate the significant medico-social problems of the patients identified through the standardized interview and apply them in practice to update the comprehensive rehabilitation program.

**SCIENTIFIC HYPOTHESIS**

From the literature review on the topic, it can be summarized that the impaired ability to perform normal locomotor activity significantly affects the overall psychosocial state of the individual and disrupts their ability to independently perform daily professional and household tasks. This necessitates the use of external assistance and leads to prolonged incapacity to work, which represents a significant medico-social issue. Early and accurate functional assessment is crucial for diagnosing, actively monitoring, and evaluating gait disturbances, as well as for assessing the effects of therapy and the prognosis for recovery. This creates high demand for kinesiotherapy in developing and implementing precise and reliable kinesiotherapeutic markers for gait evaluation. The working hypothesis of this study is formulated as follows:

***Conducting a systematic scientific study of gait parameters will provide a useful database for practice, which could help identify certain patterns in the recovery of locomotor activity in various traumatic conditions of the lower limb.***

The **OBJECT OF THE STUDY** is patients who have suffered lower limb injuries and require assistance with locomotor activity using assistive devices. These patients are grouped based on age and the location of the injury.

The **SCOPE OF THE STUDY** includes relationships, dependencies, and factor interactions and comparisons between variable quantities for the recovery of locomotor activity in patients who have suffered lower limb injuries and require walking with two underarm crutches. These patients are monitored from the beginning of the observation period until they can walk without assistive devices.

**CRITERIA for inclusion in the study**

Patients included in the study must meet the following criteria:

- ✓ Be over 18 years of age;
- ✓ Be diagnosed with a femoral fracture, an injury in the ankle-foot complex, or an anterior cruciate ligament (ACL) rupture, which may be of an earlier occurrence;
- ✓ Have undergone a traumatic-orthopedic therapeutic approach that requires locomotor activity with the use of two axillary crutches, ensuring offloading of the injured limb for a certain period.

**UNITS of Observation**

The study cohort consists of patients who sought physiotherapeutic and rehabilitative treatment at UMHAT "Dr. G. Stranski" – Pleven following lower limb trauma. A condition for inclusion in the study is that the traumatic condition requires the use of assistive devices to unload the injured limb during walking. To make a comparative analysis of locomotor activity, patients were grouped based on the localization, traumatic-orthopedic approach, type of trauma, and presence of complications such as Complex Regional Pain Syndrome (CRPS). The scientific study was conducted in a cohort of patients divided into 5 groups.

**I.** Patients with hip joint (HJ) injuries aged over 65 years;

**First Group A ($I^A$) – p**atients who underwent a traumatic orthopedic therapeutic approach with metal osteosynthesis **(Status post osteosynthesis metallica/ MO)**;

**First Group B ($I^B$)** – patients who underwent a traumatic orthopedic therapeutic approach with arthroplasty **(Status post aloplastica coxae)**;

**II.** Patients with knee joint (KJ) injury;

**Second Group (II)** – patients after anterior cruciate ligament (ACL) reconstruction, up to 65 years of age, with varying trauma duration;

**III.** Patients after injuries in the ankle-foot complex (AFC) up to 65 years of age – sprain and dislocation; fracture of the malleoli, tarsal bones, and calcaneus;

**Third Group ($III^A$)** – patients with malleolar fractures;

**Third Group ($III^B$)** – patients with Complex Regional Pain Syndrome (CRPS) as a complication following an injury to the AFC.

Based on the reviewed scientific literature and our personal observation, the conclusion has been established that there is no significant difference in the recovery of gait parameters between men and women, which means that it is not necessary to separate patients into distinct groups based on the "gender" attribute when analyzing the obtained results.

**LOCATION AND DURATION of the Study**

The patients included in the study were rehabilitated and examined at the Clinic of Physical Medicine and Rehabilitation (CPMR) – both inpatient at the Department of Hospital Rehabilitation and outpatient at the DCC of UMHAT "Dr. G. Stranski" Pleven. For each individual patient, depending on the type of injury, their condition, and the recommendations of the treating traumatologist, the ***recovery period*** is strictly individualized, but most often aligns with the generally accepted norms for unloading the injured limb (from the injury to walking without assistive devices). The

entire study was conducted from July 2023 to December 2024. The initial examination for each patient was conducted during the first rehabilitation course, and the final examination was performed when full load-bearing of the injured limb was permitted. This period is defined as the ***observed period***, which is shorter than the recovery period. The only exception is for patients with ACL reconstruction, where the recovery period is counted from the date of the surgical intervention, not from the date of the injury.

**DESIGN of the Study**

This study is observational, with the subjects selected based on their exposure status (lower limb injury) and an investigation into the recovery of their locomotor activity. The study follows a "pre-post" design, with measurements and tests performed at the beginning and at the end of the observation period. The patients included in the study represent a representative sample of individuals who sought physiotherapeutic and rehabilitation treatment following a traumatic lower limb injury. To initiate the rehabilitation process, patients must be referred by their treating traumatologist, undergo a control radiograph (for post-fracture conditions), and be prescribed a comprehensive physiotherapeutic and rehabilitation program after consultation with a physician specializing in physical and rehabilitation medicine.

**ADMINISTRATION of the Study**

To register the obtained results, a special **Individual File** has been developed, in which data from the initial and final examinations are entered. The file consists of two parts.:

- ***Passport section*** – registers name, age, address, profession, diagnosis, date of injury, and observation period;
- ***Special section*** – registers all tests, measurements, and assessments made at the beginning and end of the observation period.

During the special tests and measurements, a **standardized interview** is conducted with each patient, and a medical history is taken regarding accompanying diseases, the mechanism of the injury, lifestyle, the need for assistance in performing activities of daily living, the ability to use transportation, the possibility for social functioning, and an assessment of emotional anxiety.

In compliance with the requirements of Regulation No. 14 of 27.09.2007 on "Conditions and procedures for conducting therapeutic and non-therapeutic scientific research on human beings," a clinical "***Patient Consent Form***" for inclusion in the study has been prepared, which the patient reviews and signs.

**METHODS of the study**

To achieve the goal and implement the tasks set in this dissertation, functional, statistical, and sociological research methods were applied, as well as a proprietary methodology for functional assessment of locomotor activity.

**1.** The **functional research methods** consist of:

- ***Pain assessment – VAS (Visual Analog Scale)*** for pain evaluation from 0 to 20 points.

▪ ***Gait parameters*** – for the study, an inertial sensor (G-WALK) with appropriate software was used to record the spatial and temporal gait parameters.

▪ ***Tape measurement*** – the presence of joint swelling or muscle hypotrophy is recorded.

▪ ***Goniometry*** – assessment of the motor function in the individual joints of the lower limb using the SFRT methodology.

▪ ***ADL test*** – a four-level scale from grade 0 to grade 3.

▪ ***Locomotor Activity Test*** – assessment of locomotor activity from 0 to 15 points depending on the need for assistive devices.

**2. Methodology of Functional Assessment**

Each patient included in this study is informed about the purpose of the research and signs an informed consent form. The examination takes place in the "Kinesiotherapy" section of the Clinic of Physical and Rehabilitation Medicine (CPRM) and starts with a brief medical history and review of data from the patient's medical documentation. Tape measurement and goniometry of the lower limbs are performed, and the values are recorded in an individual file. The main part of the assessment involves gait analysis using the G-WALK inertial sensor. Each patient is registered in the software database of the device by entering their anthropometric data, age, gender, and diagnosis (Fig. 1). The sensor is placed at the S1 level (Fig. 2) of the patient, connected to a laptop via Bluetooth, and calibrated for a short period.

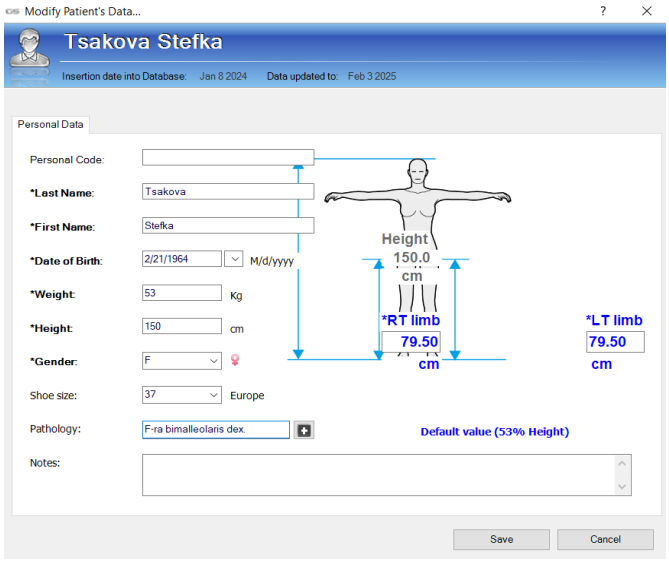



***Fig. 1 Database in the G-WALK sensor***

***Fig. 2 Placement of the G-WALK sensor***

A 10-meter flat section (corridor) has been pre-measured and marked. The patient is given instructions and walks the distance using their usual walking pattern (Fig. 3).

***Fig. 3 Walking on a flat surface with the G-WALK inertial sensor***

After completing the walking test ***(Walk+)***, an obstacle course test is conducted, which involves climbing and descending 10 steps. The patient takes the starting position in front of the staircase, then, upon command, begins climbing at their natural pace (Fig. 4).

***Fig. 4 Climbing stairs with the G-WALK inertial sensor***

Upon reaching the last step, the sensor is turned off to save the data. The same procedure is repeated when descending the stairs (Fig. 5).

***Fig. 5 Descending the stairs with the G-WALK inertial sensor***

All data from the inertial sensor are stored in the G-WALK software (Fig. 6), from where they are recorded in the patient's Individual File.

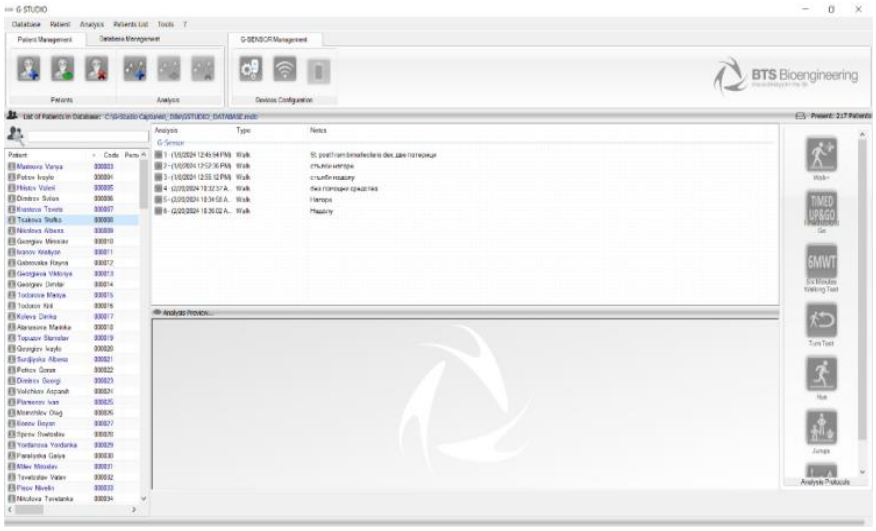



***Fig. 6 Results of patients stored in the G-WALK software***

The duration of the rehabilitation course is determined by the attending physician – a specialist in physical medicine and rehabilitation and is in accordance with the requirements of the NHIF for a period of 7 to 10 days. Depending on the degree of recovery, any complications that have occurred, and if necessary, a subsequent rehabilitation course is conducted after a break of two to three weeks, until full functional recovery is achieved, which may continue even after clearance for full loading of the injured limb.

**3. Statistical Methods**

The data from the study were processed using the SPSS statistical software, where the following were calculated: mean value ($\bar{X}$), standard deviation (SD), coefficient of variation (Cv%), statistical error (Stat. error), confidence interval (CI 95%), and t-test. The significance of the results for conclusions and inferences is determined at $p<0.05$.

**4. Sociological Methods**

A standardized interview was conducted with the patients included in this study, consisting of five groups of questions, as well as a review of medical documentation.

**CHARACTERISTICS OF THE OBSERVED COHORT**

The study included 139 patients aged between 19 and 88 years, who met the criteria for the localization of the trauma within the respective age group. The distribution of patients according to the characteristic "localization of trauma" is presented in Figure 7, which shows that injuries in the AFC are the most frequent (41,73%), followed by injuries of the HJ (35,25%) and patients with ACL reconstruction (23,02%).

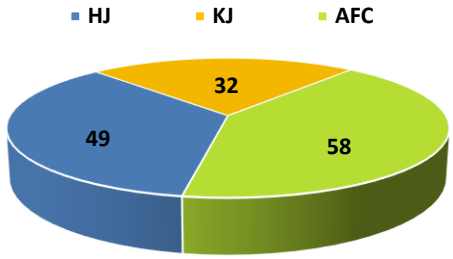



*Fig. 7 Distribution of patients in groups according to the localization of the injury*

The distribution of patients in the different groups is shown in Figure 8, which indicates that the number of patients in **Groups $I^B$, II, and $III^A$** is similar (34, 32, 35), while the numbers in **Groups $I^A$** (15) and **$III^B$** (23) are lower. For Group **$I^A$**, this can be explained by the lower frequency of pertrochanteric fractures, for which the classic traumatic-orthopedic approach is MO. The smaller number of patients in Group **$III^B$** is due to the fact that only about 30% of all injuries in the area of the AFC develop complications like CRPS. Fractures in the area of the HJ are typical for older patients (over 65 years), which is why no group was formed for younger patients.

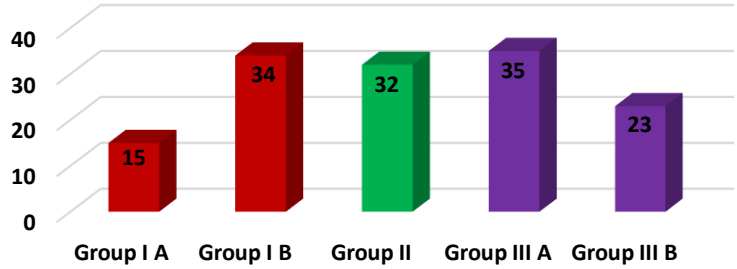



*Fig. 8 Distribution of patients in the different groups*

The distribution of all patients included in the study by the characteristic "gender" is shown in Figure 9, where it can be seen that there is no significant difference between the sexes – 72 women (51,8%) and 67 men (48,2%).

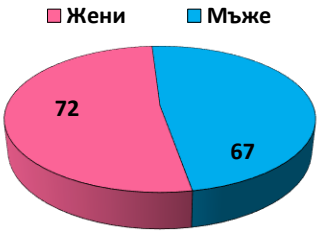



*Fig. 9 Distribution of all patients by the characteristic "gender"*

The distribution of patients by the characteristic "gender" in the separate groups is presented in Table 1, showing existing correlations between age and gender differences, as well as the type and localization of the trauma.

**Table 1 Distribution of patients in groups by the characteristic "gender"**

| **Group $I^A$** (over 65 years) | | **Group $I^B$** (over 65 years) | | **Group II** (under 65 years) | | **Group $III^A$** (under 65 years) | | **Group $III^B$** (under 65 years) | |
|---|---|---|---|---|---|---|---|---|---|
| **49** | | | | **32** | | **58** | | | |
| **15** | | **34** | | **32** | | **35** | | **23** | |
| Women | men | women | men | women | Men | women | men | women | men |
| **8** | **7** | **25** | **9** | **9** | **23** | **16** | **19** | **14** | **9** |

**The first group** includes 49 patients (33 women – 67.35% and 16 men – 32.65%) aged 67 to 88 years with femoral fractures who underwent surgical intervention. In 15 patients from subgroup **I$^{A}$** MO was performed (8 women and 7 men), while in the remaining 34 from subgroup **I$^{B}$**, arthroplasty was performed (25 women and 9 men).

**The second group** consists of 32 patients (9 women and 23 men) aged 19 to 64 years with knee joint trauma, in whom ACL injury was diagnosed and surgical reconstruction using the patellar tendon was performed.

**The third group** includes 58 patients with trauma in the AFC, aged 26 to 62 years, of whom 30 are women and 28 are men. This group is divided into two subgroups – subgroup **III$^{A}$** includes 35 patients with malleolar fractures (16 women and 19 men), while subgroup **III$^{B}$** consists of 23 patients (14 women and 9 men) with trauma in the AFC region (distortion; fractures of the metatarsal bones, calcaneus, and malleolus), in whom CRPS developed as a complication.

The next figure, Figure 10, illustrates the distribution of patients by gender across the different groups. Among patients with femoral fractures, 67,35% (33) are women, while 32,65% (16) are men. In the group of patients treated with internal fixation, there is no difference between the sexes. However, in the arthroplasty group, the number of female patients is significantly higher (73,53%), which can be attributed to osteoporotic changes, most commonly in advanced age, when the risk of falls and fractures increases. In the group of patients with ACL injuries, men predominate (71,88%), which is due to their significantly younger age and active engagement in sports at various levels. Among patients with malleolar fractures, the gender distribution is nearly equal, with a slight predominance of men (54,29%). However, CRPS as a complication of AFC trauma is observed more frequently in women (60,87%).

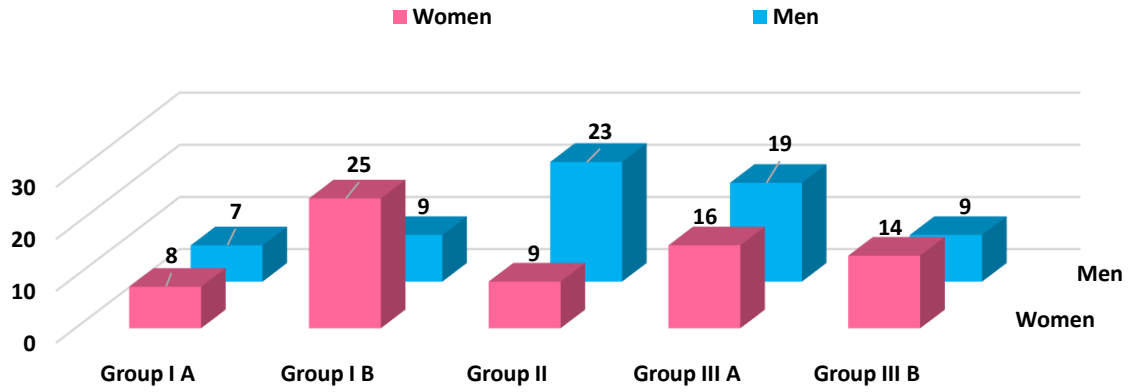



***Fig. 10 Distribution of patients in the groups by "gender"***

The instrumental examination conducted with G-WALK established that there is no significant difference in gait parameters between the two genders, except for the "step width" parameter, which is greater in women due to anatomical characteristics of the pelvis. This criterion is not a determining factor in the recovery of locomotor activity and does not necessitate considering patients in the different groups based on "gender".

Figure 11 illustrates the distribution of all patients included in the study based on the “age” criterion. This classification follows a WHO study on the need for rehabilitation services in Bulgaria, which categorizes the population into three age groups: children, young adults and elderly individuals. Since no children were included in the present study, the age distribution remains within two groups: under 65 years (young age) and over 65 years (retirement age).
The graph demonstrates a significantly higher proportion of patients with KJ and AFC injuries (64,75%) compared to fractures in the proximal femur (35,25%). This can be explained by the more active lifestyle of working individuals and the increasing risk factors for traumatic incidents, including RTA. Additionally, young individuals actively engaged in sports frequently experience sports-related injuries.

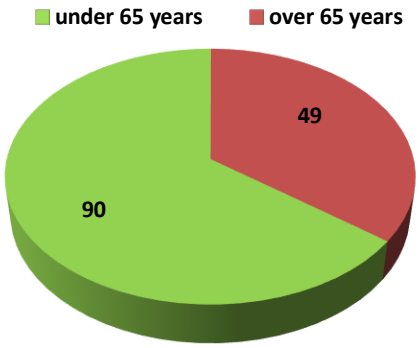
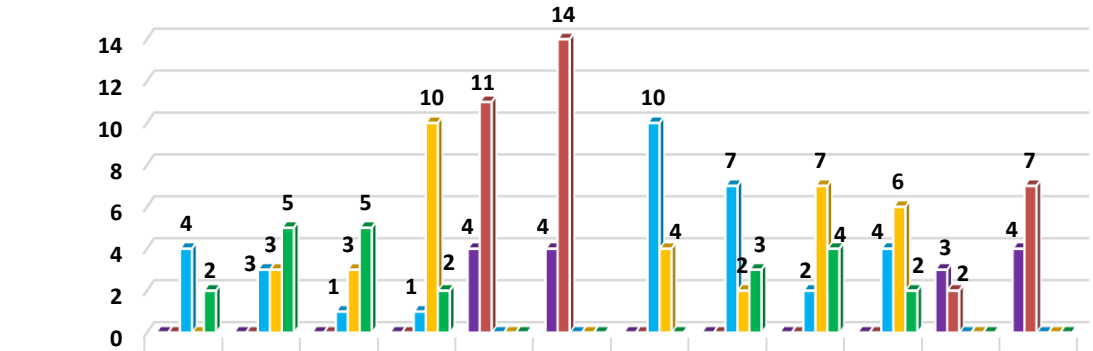



***Fig. 11 Distribution of patients by the "age" criteria***

The distribution of patients based on gender and age in the different groups is presented in Figure 12. Patients with femoral fractures are in the age group over 65 years, with 67,35% of them being women. In our study cohort, the largest proportion (41,18%) of patients with femoral neck fractures (Group **I$^{B}$**) are women over 75 years old who subsequently underwent arthroplasty, while women aged 66-75 years constitute 32,35%. The distribution of patients by age and gender in Group **I$^{A}$** is even – in the 66-75 age group, there are 4 women and 3 men, while in the over-75 group, there are 4 women and 4 men. For patients in Group **II**, it is evident that ACL injuries occur most frequently in the 19-40 age group for both genders (75%). Among them, 10 men (31,25%) and 4 women (12,50%) are between 19 and 30 years old, while 7 men (21,88%) and 3 women (9,38%) are aged 31-40 years. This confirms the increased intensity of physical activity, which predisposes individuals to torsional forces on a fixed lower leg, a common mechanism in various sports activities. The remaining 8 patients (25%), including 6 men (18,75%) and 2 women (6,25%), are over 40 years old, with injuries resulting from occupational accidents or RTA. In the group with malleolar fractures (Group **III$^{A}$**), the highest number of female patients is in the 51-65 age group (28,57%), followed by those aged 31-40 and 41-50, each accounting for 8,57%. Among men, the distribution between the 41-50 and 51-65 age groups shows a small difference (20% and 17,14%, respectively), while in the younger age groups, the proportions are 11,43% (19-30 years) and 5,71% (31-40 years). The group of patients (Group **III$^{B}$**) with injuries in the foot and AFC is heterogeneous due to the varied nature of the trauma, but they share a common

complication – CRPS. Factors contributing to the development of this condition include fractures near the joint, peripheral nerve injuries, painful repositioning and prolonged pain after a fracture and improperly applied (compressive) cast immobilization following a fracture (iatrogenic damage). The graph shows a predominance of female patients aged 31-50 years (43,48%), confirming the predisposition for disease development. The proportion of men in this group is 39,13%, accounting for approximately one-third of all patients, evenly distributed across the three age groups.




| | 19-30 (W) | 31-40 (W) | 41-50 (W) | 51-65 (W) | 66-75 (W) | over 75 (W) | 19-30 (M) | 31-40 (M) | 41-50 (M) | 51-65 (M) | 66-75 (M) | over 75 (M) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group I A | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 3 | 4 |
| Group I B | 0 | 0 | 0 | 0 | 11 | 14 | 0 | 0 | 0 | 0 | 2 | 7 |
| Group II | 4 | 3 | 1 | 1 | 0 | 0 | 10 | 7 | 2 | 4 | 0 | 0 |
| Group III A | 0 | 3 | 3 | 10 | 0 | 0 | 4 | 2 | 7 | 6 | 0 | 0 |
| Group III B | 2 | 5 | 5 | 2 | 0 | 0 | 0 | 3 | 4 | 2 | 0 | 0 |

***Fig. 12 Distribution of patients in the groups by the characteristic "gender and age"***

At the start of the study, the average arithmetic values of the initial measurements and tests of the examined variables show insignificant differences among the patients in all groups.

## RESULTS AND ANALYSIS

### 1. Results of the studies on patients with hip joint injuries

#### *1.1. Results from the Visual Analog Scale (VAS)*

The data from the statistical processing of the results obtained from the VAS for pain intensity in patients with fractures in the HJ ($I^A$ and $I^B$ groups) at the beginning and end of the observation period are presented in Table 2 and demonstrate a high level of significance ($p<0,05$).

**Table 2 VAS for pain intensity at the beginning and end of the observation period in patients from the $I^A$ and $I^B$ groups**

| Indicator | N | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **VAS – $I^A$** | 15 | 14,0 | 3,873 | 27,7 | 11,9÷16,1 | 3,0 | 3,162 | 105,4 | 1,3÷4,8 | 8,521 | =0,000 |
| **VAS – $I^B$** | 34 | 7,8 | 2,520 | 32,3 | 6,9÷8,7 | 0,7 | 1,797 | 256,7 | 0,1÷1,4 | 3,376 | =0,000 |

Results from the VAS for pain intensity at the beginning and end of the observation period in patients with HJ trauma are reflected in Figure 13. The data show that at the beginning of the study, patients in group $I^A$ reported "severe pain that restricts motor activity but is influenced by medication" (score 14), while patients in group $I^B$ reported a pain intensity of 7,8. These results confirm that patients with hip arthroplasty do not experience severe pain after surgery (as the source of pain is removed), unlike those whose surgical approach was MO (the natural joint is preserved), and during the fracture healing process, patients experience pain. At the end of the study, there is no pain reported by patients in group $I^B$ (score 0,7), while in group $I^A$, the pain decreased by 78,57%, remaining at "mild pain during normal physical activity" (score 3).

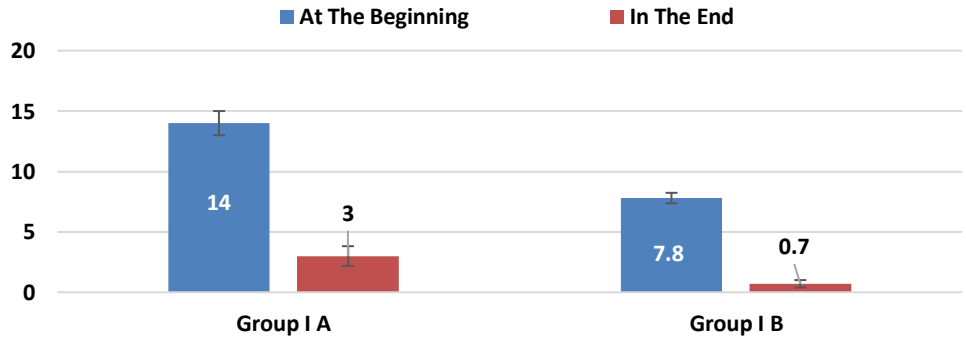



***Fig. 13 Results from the VAS for pain intensity at the beginning and end of the observation period in patients from the $I^A$ and $I^B$ groups***

#### *1.2. Results from the study of the "Support Phase" of gait*

The data from the statistical processing of the results obtained from the study of the Support Phase (SP) in % for the healthy and injured limbs of patients with fractures in the hip joint (group $I^A$ and $I^B$) at the beginning and end of the observation period are presented in Table 3.

**Table 3 Results from the measurement of the "Support Phase" at the beginning and end of the observation period in patients with fractures in the HJ from Groups $I^A$ and $I^B$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **SP – healthy limb $I^A$** | 15 | 61,2 | 3,392 | 5,5 | 59,4÷63,1 | 9,3 | 2,369 | 4,0 | 58,1÷60,8 | 1,779 | =0,086 |
| **SP – healthy limb $I^B$** | 34 | 61,9 | 1,919 | 3,1 | 61,3÷62,6 | 9,9 | 1,653 | 2,8 | 59,4÷60,5 | 4,604 | =0,000 |
| **SP – injured limb $I^A$** | 15 | 56,7 | 3,125 | 5,5 | 55,0÷58,5 | 57,8 | 3,071 | 5,3 | 56,1÷59,5 | -0,972 | =0,339 |
| **SP – injured limb $I^B$** | 34 | 57,6 | 2,543 | 4,4 | 56,7÷58,5 | 58,9 | 3,002 | 5,1 | 57,8÷59,9 | -1,937 | =0,058 |

The graphical representation of the results from the SP study in patients from Groups $I^A$ and $I^B$ at the beginning and end of the study is shown in Figure 14, where the norm for all patients is reflected within the range of 57-61%. The results from the initial measurements of the healthy limb are identical in both patient groups (61,2% and 61,9%), which is at the upper limit of the norm. For the injured limb, the results are identical – 56,7% (Group $I^A$) and 57,8% (Group $I^B$), but at the lower limit of the norm. Similar values for the healthy and injured limbs are observed, which is most likely due to the difficulty in learning to walk properly with assistive devices. This trend remains in the final measurements, with 59,4% (Group $I^A$) and 59,9% (Group $I^B$) for the healthy limb and 57,8% and 58,9% for the injured limbs of both groups, all within the normal range. The initial and final measurements for patients with MO do not have statistical significance (p=0,086 and p=0,339), indicating that the improvement in this indicator is minimal and statistically insignificant. The baseline and final results for patients with arthroplasty for the healthy limb are statistically significant (p=0,000), while those for the injured limb have a borderline value for significance at p=0,058. The analysis of the data for the recovery of the support phase of gait in patients with HJ fractures confirms our clinical observation that in elderly patients, there is no significant difference between the support phase of the healthy and injured limbs.

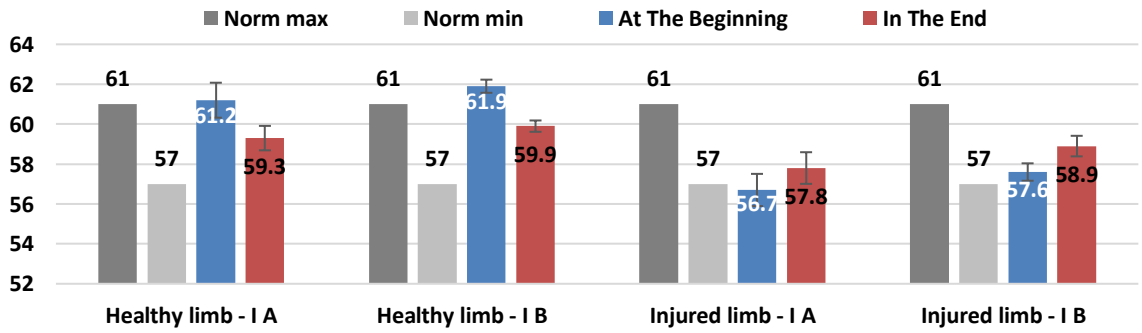



***Fig. 14 Results of the "Support Phase" gait study for the healthy and injured limbs at the beginning and end of the study period in groups $I^A$ and $I^B$***

### *1.3. Results of the "Speed" study*

Table 4 presents the data from the statistical processing of the "Speed" parameter for movement on flat terrain (10 meters), as well as for ascending and

descending stairs (10 steps), recorded in meters per second, at the beginning and end of the study period for patients in the $I^A$ and $I^B$ groups ($p<0,05$).

**Table 4 Statistical processing of the results for "Speed" (m/s) of walking on flat terrain, ascending, and descending stairs at the beginning and end of the observation period in patients from $I^A$ and $I^B$ groups**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **Speed on flat terrain – Group $I^A$** | 15 | 0,341 | 0,139 | 0,8 | 0,264÷0,419 | 0,845 | 0,153 | 18,1 | 0,760÷0,930 | -9,443 | =0,000 |
| **Speed on flat terrain – Group $I^B$** | 34 | 0,469 | 0,199 | 42,4 | 0,833÷0,226 | 0,833 | 0,226 | 27,1 | 0,754÷0,912 | -7,048 | =0,000 |
| **Speed of climbing stairs – Group $I^A$** | 15 | 0,489 | 0,098 | 20,0 | 0,435÷0,543 | 0,751 | 0,125 | 16,6 | 0,682÷0,821 | -6,388 | =0,000 |
| **Speed of climbing stairs – Group $I^B$** | 34 | 0,509 | 0,129 | 25,3 | 0,464÷0,554 | 0,837 | 0,232 | 27,7 | 0,756÷0,918 | -7,205 | =0,000 |
| **Speed of descensing stairs – Group $I^A$** | 15 | 0,477 | 0,133 | 27,9 | 0,404÷0,551 | 0,709 | 0,153 | 21,6 | 0,624÷0,794 | -4,432 | =0,000 |
| **Speed of descensing stairs – Group $I^B$** | 34 | 0,504 | 0,157 | 31,2 | 0,449÷0,559 | 0,805 | 0,198 | 24,6 | 0,736÷0,918 | -6,946 | =0,000 |

Figure 15 reflects the results of the "Speed" test for walking on flat terrain, ascending, and descending stairs for patients in the $I^A$ and $I^B$ groups at the beginning and end of the observation period, measured in m/s. The graph shows identical results at the start of the study for patients in both groups across all three types of measurements: walking on flat terrain (0.341 m/s for the $I^A$ group and 0,469 m/s for the $I^B$ group); stair ascent – 0,489 m/s and 0,509 m/s, respectively; stair descent – 0,477 m/s and 0,504 m/s. The final results show improvements, but there are no significant differences between the groups when walking on flat terrain (0,845 m/s and 0,833 m/s). The results for stair ascent at the end of the study improve to 0,751 m/s for patients with MO, and to 0,837 m/s for those with arthroplasty. Stair descent shows no significant difference between the results in both groups (0,709 m/s and 0,805 m/s). The data in the graph shows higher absolute values for stair navigation compared to walking on flat terrain, since 10 stairs do not correspond to 10 meters of flat terrain.

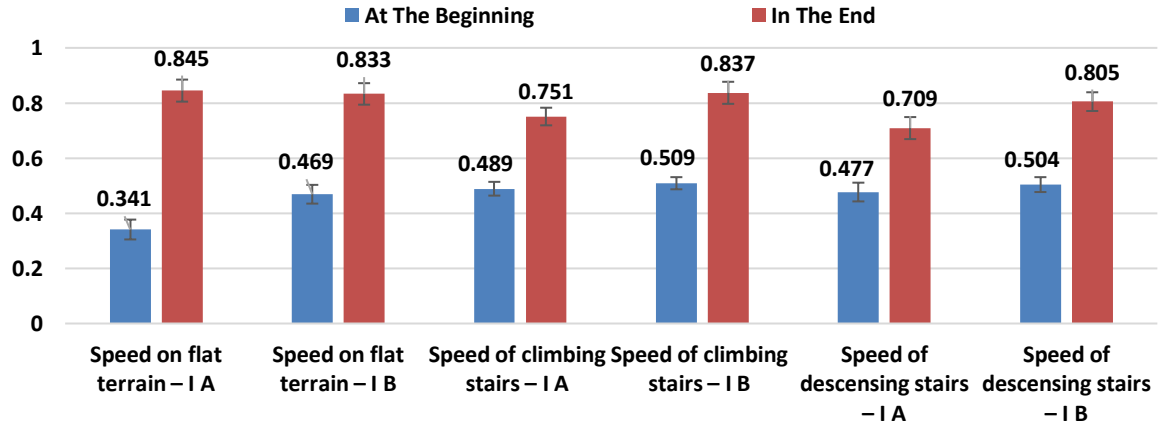



***Fig. 15 Results of the "Speed" test for walking on flat terrain, ascending and descending stairs at the beginning and end of the observation period in the $I^A$ and $I^B$ groups***

### *1.4. Results of the study on "Pelvic Oscillation" in the sagittal, frontal and transverse planes*

The statistical data on "Pelvic Oscillation" in the sagittal (S), frontal (F), and transverse (T) planes, recorded as a percentage (%), with a normal range of 90-100% for each individual parameter, from the beginning to the end of the study period for patients in groups $I^A$ and $I^B$, are presented in Table 5.

**Table 5 Statistical analysis of the results of "Pelvic Oscillation" at the beginning and end of the observation period in patients from groups $I^A$ and $I^B$**

| Indicator | n | At The Beginning | | | | In The End | | | | t-test | p |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | | |
| **S – $I^A$** | 15 | 68,8 | 26,606 | 1,7 | 49,1÷78,6 | 1,7 | 12,852 | 17,9 | 64,6÷78,8 | -1,036 | =0,313 |
| **S – $I^B$** | 34 | 76,4 | 17,888 | 23,4 | 70,2÷82,7 | 9,1 | 13,927 | 20,2 | 64,3÷74,0 | 1,878 | =0,065 |
| **F – $I^A$** | 15 | 46,4 | 27,669 | 59,6 | 31,1÷61,7 | 5,2 | 14,407 | 19,2 | 67,2÷83,1 | -3,576 | =0,001 |
| **F – $I^B$** | 34 | 52,6 | 26,263 | 49,9 | 43,4÷61,7 | 2,2 | 18,027 | 25,0 | 65,9÷78,5 | -3,588 | =0,001 |
| **T – $I^A$** | 15 | 47,7 | 29,960 | 62,8 | 31,1÷64,3 | 0,2 | 11,826 | 14,7 | 73,6÷86,7 | -3,908 | =0,001 |
| **T – $I^B$** | 34 | 73,0 | 18,802 | 25,8 | 66,5÷79,6 | 0,5 | 14,183 | 17,6 | 75,6÷85,5 | -1,857 | =0,068 |

Figure 16 presents the results of the study on "Pelvic Oscillation" in patients from groups $I^A$ and $I^B$ at the beginning and end of the observation period, expressed as percentages. Notably, at the start of the observation period, pelvic oscillation in the frontal plane showed the lowest values for both groups, indicating the greatest asymmetry (46,4% and 52,6%), as well as in the transverse plane for patients with metal endoprostheses (47,7%). This can be explained by the presence of severe pain resulting from the surgical intervention, which hinders knee lifting (hip flexion) during the initial swing phase, thereby compensating for limb shortening through pelvic elevation. The initial values in the sagittal plane were 68,8% (group $I^A$) and 76,4% (group $I^B$), indicating better results for patients with alloplastic implants due to lower pain levels. The final results demonstrated significant improvements in pelvic oscillation in the transverse plane for both groups, with the most substantial improvement observed in patients with metal endoprostheses (41,15% increase, reaching 80,2%) (p=0,001). For group $I^B$, this value was 80,5%, but the improvement was less pronounced (p=0,068). The final results for pelvic oscillation in the sagittal plane in patients with alloplastic implants (69,1%) indicate that when assistive devices are removed, gait becomes more challenging, leading to oscillation in the anterior-posterior direction (observed as pelvic inclination with forward trunk bending) (p=0,065). In group $I^A$, the improvement was minimal (71,7%) and not statistically significant (p=0,313). The most significant improvement in pelvic oscillation was observed in the frontal plane for both groups (75,2% and 72,2%). This improvement is attributed to pain reduction; however, the results remain far from the normal range (90-100%), which could be due to the characteristics and specificities of the respective age group.

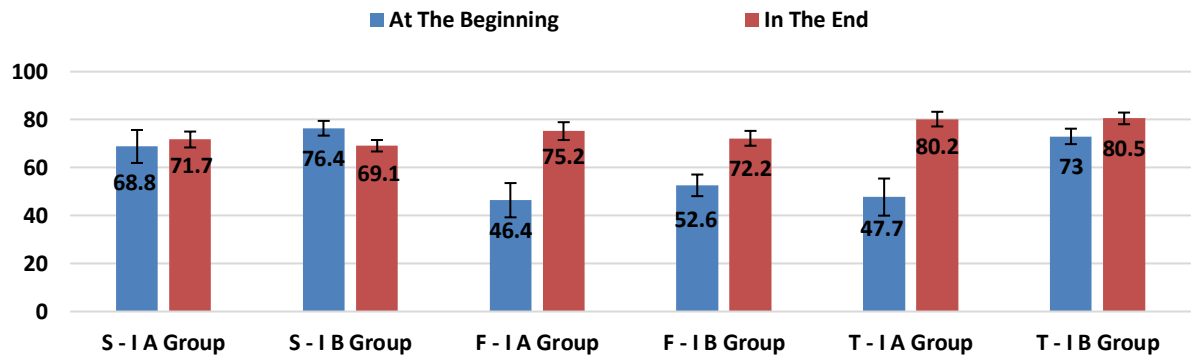



***Fig. 16 Results of the study on "Pelvic Oscillation" at the beginning and end of the observation period in patients from groups $I^A$ and $I^B$***

### *1.5. Results of the study on "Symmetry Index"*

Table 6 presents the statistical data on the "Symmetry Index," recorded as a percentage (%), with a normal range of 90-100%, from the beginning to the end of the study period for patients in groups $I^A$ and $I^B$.

**Table 6 Statistical analysis of the results of the Symmetry Index (SI) at the beginning and end of the observation period in patients from groups $I^A$ and $I^B$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **SI – $I^A$** | 15 | 79,9 | 10,780 | 13,5 | 74,0÷85,9 | 2,1 | 14,078 | 17,1 | 74,3 ÷ 89,9 | -0,481 | =0,645 |
| **SI – $I^B$** | 34 | 84,5 | 6,298 | 7,5 | 82,3÷86,7 | 9,4 | 5,997 | 6,7 | 87,3 ÷ 91,5 | -3,285 | =0,002 |

Figure 17 presents the results of the study on the Symmetry Index (SI) in patients from groups $I^A$ and $I^B$ at the beginning and end of the observation period, expressed as a percentage. This index integrates multiple gait characteristics and provides the most accurate demonstration of asymmetry and deviations in spatiotemporal parameters. At the beginning of the study, the SI value for patients with metal endoprostheses (group $I^A$) was 79,9%, increasing to 82,1% in the final measurements. However, this minimal improvement was not statistically significant (p=0,645). In contrast, for patients with arthroplasty, the SI improved from 84,5% at the start of the study to 89,4% by the end, a statistically significant change (p=0,002). Despite this improvement, the final results for both groups did not reach the normal range (90-100%), which could be attributed to the age-related characteristics of the patients in these groups.

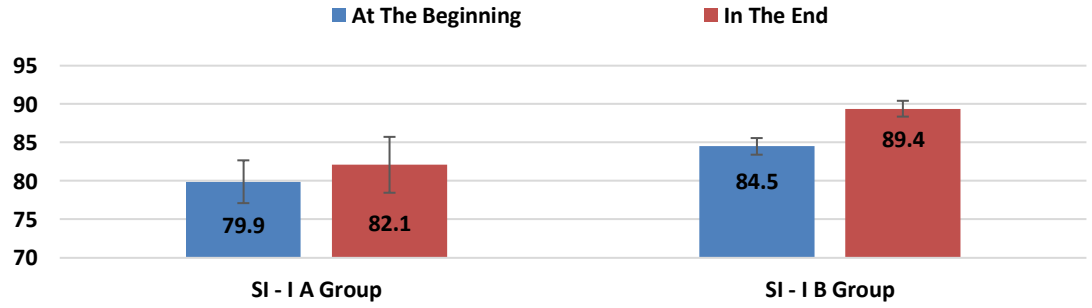



***Fig. 17 Results of the SI assessment at the beginning and end of the observation period in patients from groups $I^A$ and $I^B$***

## 2. Results of the conducted studies on patients with Anterior Cruciate Ligament Reconstruction

### *2.1. Results from the Visual Analog Scale (VAS)*

The statistical analysis of the VAS results for patients with anterior cruciate ligament (ACL) reconstruction at the beginning and end of the rehabilitation period is presented in Table 7 and demonstrates a high level of significance (p<0,05).

**Table 7 Visual Analog Scale (VAS) for pain intensity at the beginning and end of the observation period in patients with ACL reconstruction (group II)**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **VAS – II** | 35 | 13,6 | 4,063 | 29,9 | 12,1÷14,1 | 3 | 3,326 | 110,9 | 1,8÷4,2 | 11,411 | =0,000 |

The results of the VAS for pain in patients with lower limb trauma and ACL reconstruction are presented in Figure 18. It shows that at the beginning of the study, the values were 13,6 (a level closer to "severe pain, limiting motor activity, but responsive to medication"). By the end of the observation period, it reduced to level 3 ("no pain" or "mild pain during normal motor activity"), representing 77,94% of the baseline values (p=0,000). Pain is a dominant symptom in lower limb trauma, and its favorable reduction by the end of the rehabilitation process is crucial for restoring gait without the use of assistive devices.

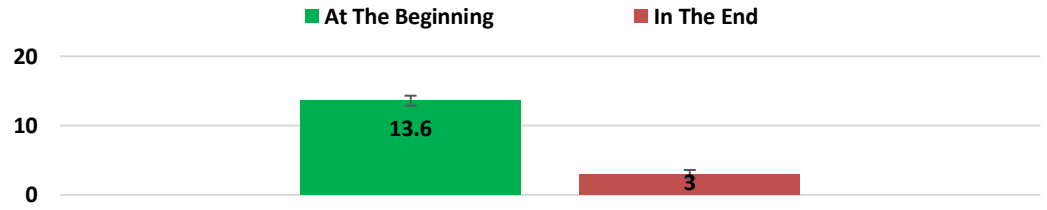



***Fig. 18 Results of the VAS for pain intensity at the beginning and end of the observation period in patients with ACL reconstruction (group II)***

### *2.2. Results of the study on "Support Phase" and "Single Support" of gait*

The statistical data on the results of the study of the SP and SS in % for healthy and injured limbs in patients with ACL reconstruction at the beginning and end of the observation period are presented in Table 8 and demonstrate a high level of significance (p<0,05).

**Table 8 Support phase of the healthy and injured limb at the beginning and end of the observation period in patients with ACL reconstruction (group II)**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **SP – healthy limb** | 32 | 67,2 | 5,628 | 8,4 | 65,3÷69,3 | 62,5 | 3,552 | 5,7 | 61,2÷63,7 | 4,117 | =0,000 |
| **SP – injured limb** | 32 | 50,9 | 5,560 | 10,9 | 49,0÷52,8 | 59,1 | 3,280 | 5,5 | 57,9÷60,3 | -7,229 | =0,000 |
| **SS – healthy limb** | 32 | 49,3 | 5,518 | 11,2 | 47,3÷51,3 | 40,6 | 3,073 | 7,6 | 39,5÷41,7 | 7,812 | =0,000 |
| **SS – injured limb** | 32 | 32,8 | 5,804 | 17,7 | 30,7÷34,9 | 37,5 | 3,370 | 9,0 | 36,3÷38,8 | -3,988 | =0,000 |

The results of the SP and SS for the healthy and injured limbs from the initial and final measurements, along with the normal range for these characteristics, are presented in Figure 19. The graph shows that at the beginning of the observation period, the SP for the healthy limb (67,2%) was above the normal range, while for the injured limb (50,9%), it was below it. This can be explained by the quicker transition through support with the injured limb to bear the weight on the healthy one. By the end of the observation period, this difference decreased – 62,5% for the healthy limb and 59,1% for the injured limb, with the normal range being between 57% and 61%. The initial results of SS for the healthy limb (49,3%) are interpreted similarly to those of the SP – values higher than normal at the start, which decreased to 40,6% by the end of the study, falling within the normal range. For the injured limb, the results follow the same pattern: at the beginning of the study, SS was 32,8%, and at the end, it reached 37,5%, with the normal range being between 36,3% and 41,4%.

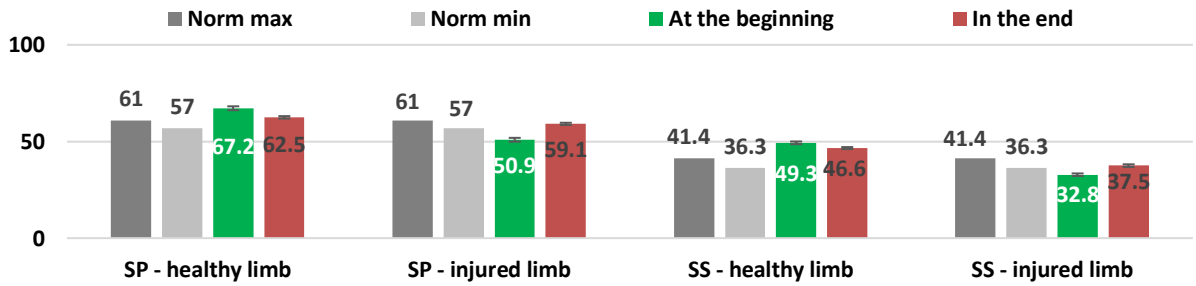



***Fig 19 Results of the study on the SP and SS of gait for the healthy and injured limb at the beginning and end of the observation period in patients from Group II, presented in %***

### *2.3. Results of the study on "Speed"*

Table 9 presents the statistical data on the "Speed" parameter on flat terrain (10 meters), as well as during stair ascent and descent (10 steps), recorded in meters per second, at the beginning and end of the observation period for patients in group II ($p<0,05$).

**Table 9 Statistical processing of the results for "Speed" (m/s) of walking on flat terrain, ascending and descending stairs at the beginning and end of the observation period in patients from group II**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **Flat terrain** | 32 | 0,568 | 0,228 | 40,1 | 0,486÷0,651 | 0,964 | 0,220 | 22,8 | 0,885÷1,044 | -7,070 | =0,000 |
| **Ascending stairs** | 32 | 0,681 | 0,355 | 52,1 | 0,553÷0,809 | 1,171 | 0,407 | 34,8 | 1,024÷1,318 | -5,101 | =0,000 |
| **Descending stairs** | 32 | 0,717 | 0,239 | 33,3 | 0,553÷0,809 | 1,303 | 0,458 | 35,2 | 1,137÷1,468 | -6,417 | =0,000 |

The results of the speed measurements are presented graphically in Figure 20. It is important to note that a comparison between the walking speed on flat terrain and stair navigation is not made, as 10 steps do not correspond to a 10-meter walk on flat terrain. In the final measurements, an increase in speed on flat terrain is recorded – from 0,568 m/s to 0,964 m/s, which is expected given the age characteristics of the patients in this group. Stair navigation is a significant challenge

for any patient with lower limb trauma, which is confirmed in this study as well. The baseline values for stair ascent speed are 0,681 m/s, and for descent, it is 0,717 m/s. By the end of the observation period, these values reach 1,171 m/s for ascent and 1,303 m/s for descent, showing an improvement of 58,16% for ascent and 55,03% for descent.

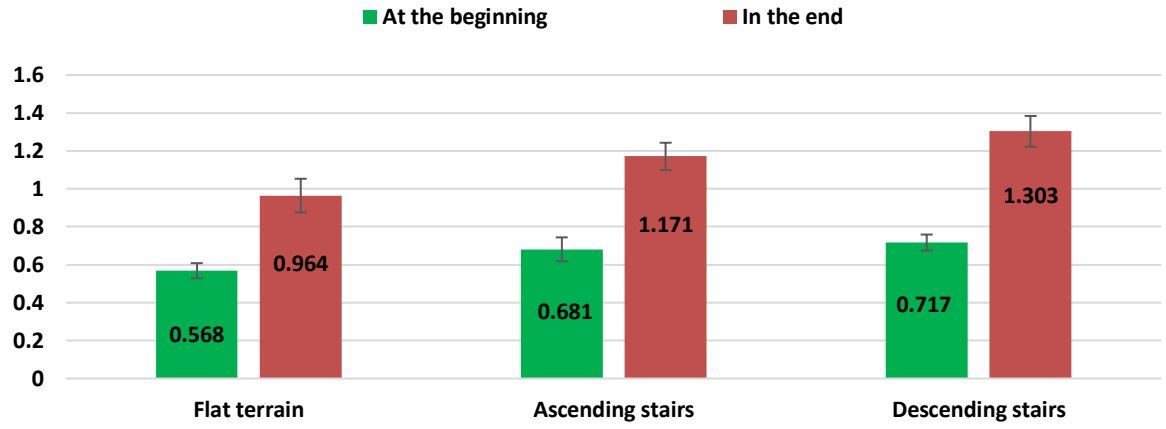



***Fig. 20 Results of the "Speed" test for walking on* flat terrain, ascending and descending stairs *at the beginning and end of the observation period in patients from Group II***

## *2.4. Results of the study on "Pelvic Oscillation" in the sagittal, frontal and transversal planes*

Table 10 presents the statistical data on "Pelvic Oscillation" in the sagittal, frontal, and transversal planes, recorded in percentages (with a normal range of 90-100%) for each individual parameter, at the beginning and end of the observation period for patients in group II, with p<0,05.

**Table 10 Statistical analysis of the results of "Pelvic Oscillation" at the beginning and end of the observation period in patients from group II**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **Pelvic Oscillation – S** | 32 | 36,2 | 22,393 | 61,9 | 28,1÷44,3 | 49,2 | 25,227 | 51,2 | 40,2÷58,3 | -2,191 | =0,032 |
| **Pelvic Oscillation – F** | 32 | 71,9 | 23,292 | 32,4 | 63,5÷80,3 | 92,2 | 13,935 | 15,1 | 87,2÷97,2 | -4,231 | =0,000 |
| **Pelvic Oscillation – T** | 32 | 73,4 | 24,758 | 33,7 | 64,5÷82,3 | 90,9 | 15,066 | 16,6 | 85,5÷96,4 | -3,419 | =0,001 |

Figure 21 presents the results of the study on pelvic oscillations in the three planes (S, F, T) at the beginning and end of the observation period for patients with ACL reconstruction (Group II). From the graphical representation of the data, it is evident that the initial values for pelvic oscillations in the sagittal plane (36,2%) are lower compared to the frontal (71,9%) and transversal (73,4%) planes. This is due to the specificity and chronicity of the injury, which involves quadriceps femoris hypotrophy and difficulty in "locking" the knee when the injured limb contacts the ground. By the end of the observation period, pelvic oscillation improves in all planes

as follows: S – 49,2%, F – 92,2%, and T – 90.9%, with values for the frontal and transversal planes reaching the lower boundary of the normal range. However, the sagittal plane still shows a tendency for lower values. This can be explained by the initially incorrect gait kinematics, caused by poor posture and muscle weakness.

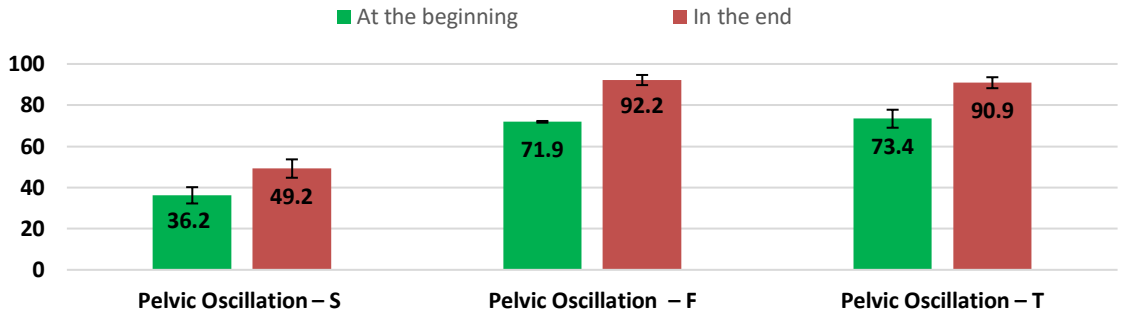



***Fig. 21 Results of the "Pelvic Oscillation" study in the S, F, T planes at the beginning and end of the observation period in patients from group II***

### *2.6. Results of the study on "Symmetry Index"*

Table 11 presents the data from the statistical analysis for the "Symmetry Index," recorded in percentages (with a norm of 90-100%) from the beginning and the end of the study period for patients in group II ($p<0,05$).

**Table 11 Statistical processing of the results of the SI at the beginning and end of the observation period in patients from group II**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **SI** | 32 | 69,7 | 14,414 | 20,7 | 64,5 ÷ 74,8 | 90,8 | 7,636 | 8,4 | 88,0÷93,5 | -7,327 | =0,000 |

Figure 22 reflects the results of the study on the SI in patients from group II at the beginning and the end of the observation period, presented in percentages. The SI combines multiple gait characteristics and most accurately demonstrates the presence of various deviations in the spatio-temporal parameters. The initial results were 69,7%, which are similar to those of the F and T planes of pelvic oscillation, and by the end of the study, they reached 90,8%, which is a result falling within the lower limit of the normal range.

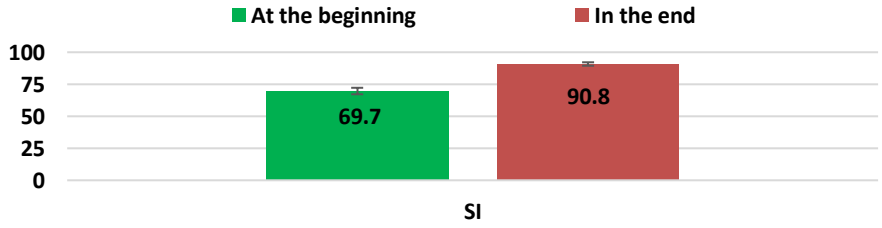



***Fig. 22 Results of the SI study at the beginning and end of the observation period in patients from group II***

## 3. Results from the studies conducted on patients with injuries in the Ankle-Foot Complex

### *3.1. Results from the Visual Analog Scale (VAS)*

The data from the statistical analysis of the results obtained from the VAS for pain intensity are presented in Table 12 and demonstrate a high level of significance ($p<0,05$). The recorded results at the beginning of the observation period show the presence of persistent pain, especially in patients from group $III^B$, who were diagnosed with a complication of CRPS. In the final results, a significant reduction in pain is observed in patients with malleolar fractures (group $III^A$), but in those with complications (group $III^B$), pain remains at higher levels.

**Table 12 VAS for pain intensity at the beginning and end of the observation period in patients from groups $III^A$ and $III^B$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **VAS – $III^A$** | 35 | 12,9 | 3,040 | 23,6 | 11,9÷14,1 | 6,1 | 3,532 | 57,9 | 4,8÷7,4 | 13,277 | =0,000 |
| **VAS – $III^B$** | 23 | 13,2 | 5,389 | 41,7 | 11,0÷15,4 | 8,7 | 4,713 | 54,2 | 6,8÷10,6 | 2,963 | =0,005 |

The results from the VAS for pain intensity at the beginning and end of the observation period in patients from the two groups with trauma in the AFC are shown in Figure 23. It is evident that at the beginning of the observation period, all patients rate the pain as "severe and limiting motor activity, but responsive to pain-relieving medications" (score of 12,9 for group $III^A$ and 13,2 for group $III^B$). Our clinical observation reveals that since patients self-assess, this rating is often influenced by their psycho-emotional state, which can be explained as a sense of uncertainty and fear. At the end of the study, pain levels decrease to a score of 6,1 in group $III^A$, representing a 52,71% reduction and bringing it closer to being described as "mild and intermittent during normal physical activity." In patients from group $III^B$, pain also decreases to a score of 8,7 (a 34,09% improvement), but it is closer to being described as "moderate pain during walking, resolving with rest." In both groups, despite the prolonged period of limb unloading and the rehabilitation program, residual pain remains, manifesting only with physical overexertion and subsiding with rest. However, in patients with CRPS complications (group $III^B$), the pain intensity is 2,6 points higher.

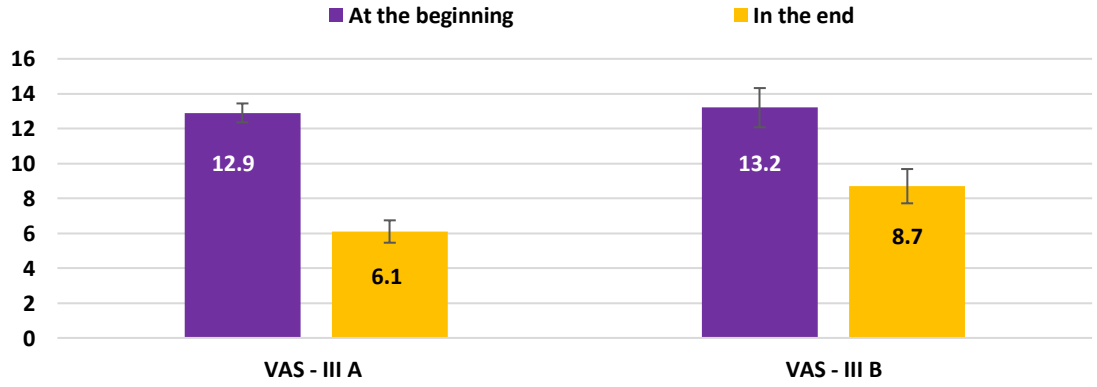



***Fig. 23 Results of VAS for pain intensity at the beginning and end of the observation period in patients from groups $III^A$ and $III^B$***

### *3.2. Results from the "Support Phase" of gait*

Table 13 presents the statistical data from the processing of the "Support Phase" parameter at the beginning and end of the observation period, including double support and SS for the healthy limb and double support and SS for the injured limb in patients from groups $III^A$ and $III^B$. Double support in the support phase varies between 7,2% and 13,4% (norm), and due to its small share in the walking cycle, it is not subject to discussion in this study ($p<0,05$).

**Table 13 Results of SP measurements at the beginning and end of the observation period in patients with injuries in the AFC from groups $III^A$ and $III^B$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **SP-healthy limb $III^A$** | 35 | 68,6 | 4,259 | 6,2 | 67,1÷70,1 | 64,4 | 4,324 | 6,7 | 62,5÷65,6 | 4,946 | =0,000 |
| **SP-healthy limb $III^B$** | 23 | 69,3 | 2,792 | 4,0 | 68,2÷70,4 | 67,5 | 3,668 | 5,4 | 66,0÷69,0 | 1,823 | =0,075 |
| **SP-injured limb $III^A$** | 35 | 52,8 | 4,353 | 8,2 | 51,3÷54,3 | 56,8 | 3,073 | 5,4 | 55,7÷57,9 | -4,221 | =0,000 |
| **SP-injured limb $III^B$** | 23 | 51,7 | 2,139 | 4,1 | 50,8÷52,6 | 53,2 | 2,131 | 4,0 | 52,3÷54,0 | -2,343 | =0,023 |

Figure 24 graphically presents the SP from the walking cycle at the beginning and end of the observation period of the healthy or injured limb in patients from groups $III^A$ and $III^B$. At the beginning of the study, the SP of the healthy limb in patients with malleolar fractures (group $III^A$) is 68,6%, and for the injured limb, it is 52,8%, with a normal SP range of 57% – 61% (in normal gait, the SP occupies a larger portion of the SW). In patients from group $III^B$ (with complications of CRPS), the results are identical – 69,3% for SP of the healthy limb and 51,7% for the injured limb. These results show that a larger portion of the SP in all patients with injuries to the AFC occurs from compensatory load on the healthy limb, causing a significant shortening of the SW (31,4% for patients from group $III^A$ and 30,7% for patients from group $III^B$). At the end of the study, the SP values for the healthy limb in patients from group $III^A$ decreased by 4,2% to 64,4%, while the SP for the injured limb increased by 4% to 56,8% ($p=0,075$). The SP of the healthy limb is still 3,4% above the normal range, and the injured limb reaches the lower boundary of the normal range (57%). During the recovery process, the normal SP values are gradually reached for patients with malleolar fractures. These results can be explained by the reduction of compensatory load on the healthy limb, as the injured limb begins to bear more of the body's weight and gradually returns to function, handling more physical load. The increase in SP for the injured limb is a good indicator of functional recovery in gait. The final results for patients with complications (group $III^B$) are 67,5% (upper limit of normal 61%) for SP of the healthy limb and 53,2% (lower limit of normal 57%) for SP of the injured limb. Compared to patients without complications, the SP results do not fall within the normal range. This gait parameter, along with the limited range of dorsiflexion in the ankle joint and the presence of pain due to the complication, hinders the ability to perform locomotor activity without assistive devices, despite the absence of contraindications.

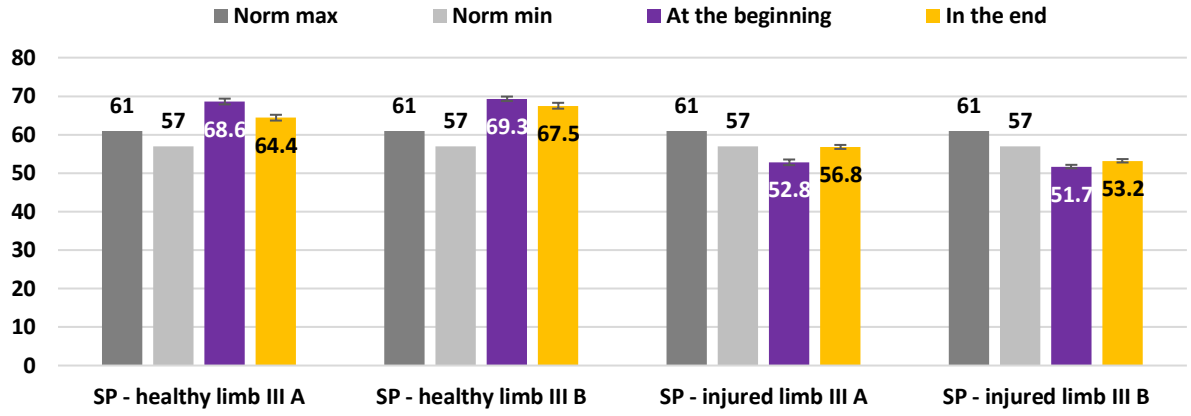



***Fig. 24 Results of the SP of gait for the healthy and injured limb at the beginning and end of the observation period in groups III$^{A}$ and III$^{B}$***

### *3.3. Results of the study on "Speed"*

На Таблица 14 са представени данните от статистическата обработка на параметър „Скорост" на придвижване по равен терен (10 метра), при изкачване и слизане на стълби (10 стъпала), регистрирани в метри/секунда, в началото и края на изследвания период при пациентите от III$^{А}$ и III$^{Б}$ групи (p<0,05).

**Table 14 Statistical processing of the results for "Speed" (m/s) of walking on flat terrain, ascending and descending stairs at the beginning and end of the observation period in patients from group III$^{A}$ and III$^{B}$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **Flat terrain – III$^{A}$** | 35 | 0,615 | 0,201 | 32,7 | 0,546÷0,684 | 0,864 | 0,169 | 19,6 | 0,806÷0,922 | -0,249 | =0,000 |
| **Flat terrain – III$^{B}$** | 23 | 0,627 | 0,038 | 6,1 | 0,611÷0,643 | 0,835 | 0,043 | 5,2 | 0,817÷0,853 | -16,867 | =0,000 |
| **Ascending stairs – III$^{A}$** | 35 | 0,683 | 0,277 | 40,6 | 0,588÷0,778 | 1,092 | 0,319 | 29,2 | 0,982÷1,201 | -8,634 | =0,000 |
| **Ascending stairs – III$^{B}$** | 23 | 0,657 | 0,050 | 7,6 | 0,637÷0,677 | 0,964 | 0,095 | 9,9 | 0,925÷1,003 | -13,409 | =0,000 |
| **Descending stairs – III$^{A}$** | 35 | 0,651 | 0,230 | 35,4 | 0,571÷0,729 | 0,945 | 0,292 | 30,9 | 0,845÷1,045 | -7,273 | =0,000 |
| **Descending stairs – III$^{B}$** | 23 | 0,672 | 0,085 | 12,7 | 0,637÷0,707 | 0,897 | 0,144 | 16 | 0,838÷0,956 | -6,318 | =0,000 |

Figure 25 presents the results of the study on "Speed" during level walking, stair ascent, and stair descent in patients from groups III$^{A}$ and III$^{B}$ at the beginning and end of the observation period. The graph shows identical initial results for both groups across all three measurements: level walking (0,615 for group III$^{A}$ and 0,627 for group III$^{B}$); stair ascent (0,683 and 0,657 respectively); and stair descent (0,651 and 0,672 respectively). The final results show improvement but remain without significant differences between the groups in level walking (0,864 and 0,835). The stair ascent results at the end of the study improve to 1,092 in patients with malleolar fractures, while those with CRPS complications improve to 0,964. Stair descent does not show a significant difference between the groups (0,945 and 0,897). The data in the graph indicate higher absolute values when climbing stairs compared to level walking, as 10 steps do not correspond to 10 meters of level ground.

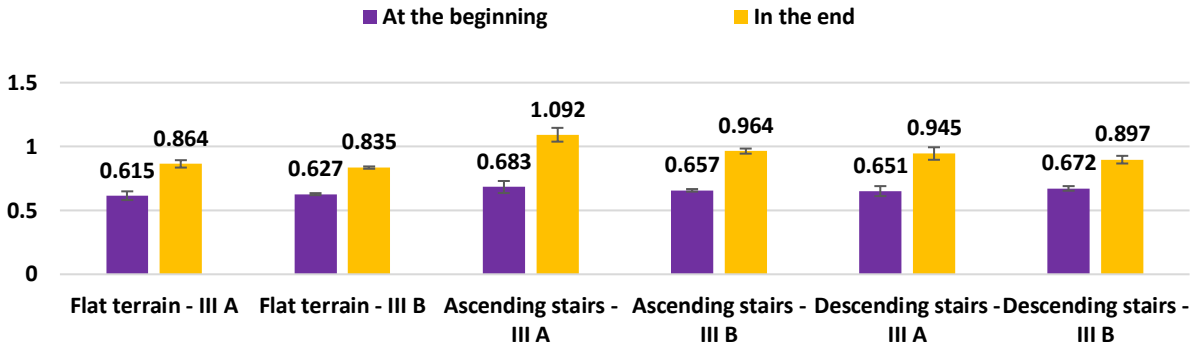



***Fig. 25 Results of the "Speed" test for walking on* flat terrain, ascending and descending stairs *at the beginning and end of the observation period in patients from III$^A$ and III$^B$ groups***

### *3.4. Results of the study on "Pelvic Oscillation" in the sagittal, frontal and transversal Planes*

Table 15 presents the statistical data for "Pelvic Oscillation" in the sagittal, frontal, and transversal planes, recorded in percentages (normal range 90-100%) for each parameter at the beginning and end of the study period for patients in groups III$^A$ and III$^B$ ($p<0,05$).

**Table 15 Statistical processing of the results of "Pelvic Oscillation" at the beginning and end of the observation period in patients from groups III$^A$ and III$^B$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **S – III$^A$** | 35 | 31,5 | 21,530 | 68,3 | 24,1÷38,9 | 46,2 | 24,005 | 52,0 | 37,9÷54,4 | -2,667 | =0,011 |
| **S – III$^B$** | 23 | 30,7 | 8,642 | 28,1 | 27,2÷34,2 | 45,7 | 9,573 | 20,9 | 41,8÷49,6 | -5,455 | =0,000 |
| **F – III$^A$** | 35 | 78,2 | 16,048 | 20,5 | 72,7÷83,8 | 86,6 | 13,657 | 15,8 | 81,9÷91,3 | -2,710 | =0,010 |
| **F – III$^B$** | 23 | 74,6 | 7,556 | 10,1 | 71,5÷77,7 | 82,8 | 8,439 | 10,2 | 79,4÷86,2 | -3,399 | =0,002 |
| **T – III$^A$** | 35 | 78,0 | 25,072 | 32,1 | 69,4÷86,6 | 90,0 | 15,055 | 16,7 | 84,8÷95,1 | -3,346 | =0,001 |
| **T – III$^B$** | 23 | 76,6 | 8,770 | 11,7 | 73,0÷80,2 | 88,5 | 6,549 | 7,4 | 85,8÷91,2 | -5,110 | =0,000 |

Figure 26 reflects the results of the "Pelvic Oscillation" study in patients from groups III$^A$ and III$^B$ at the beginning and end of the observation period. It is noteworthy that at the start of the observation period, the pelvic oscillations in the sagittal plane are the lowest in both groups (31,5% for group III$^A$ and 30,7% for group III$^B$) compared to the other two planes, which can be explained by the body position and the change in gait mechanics when walking with crutches ($p=0,011$). The results of pelvic oscillations in the frontal (78,2% for group III$^A$ and 74,6% for group III$^B$) ($p=0,010$) and transversal (78% for group III$^A$ and 76,6% for group III$^B$) ($p=0,001$) planes are higher compared to the sagittal plane, with only a minor difference observed between patients with complications (CRPS) and those with malleolar fractures. Final measurements show an improvement of about one-third in the pelvic oscillations in the sagittal plane, but values are still about half of the normal range. This trend is most likely due to postural control disorders, with the presence of lower crossed syndrome resulting from prolonged locomotor activity with assistive devices and adopting faulty positions in daily life. The final values in the frontal and transversal planes for patients in group III$^A$ approach the lower limit of the normal

range – 86,6% (F) and 90% (T), while patients in group III$^{B}$ show slightly lower values – 82,8% (F) and 88,5% (T).

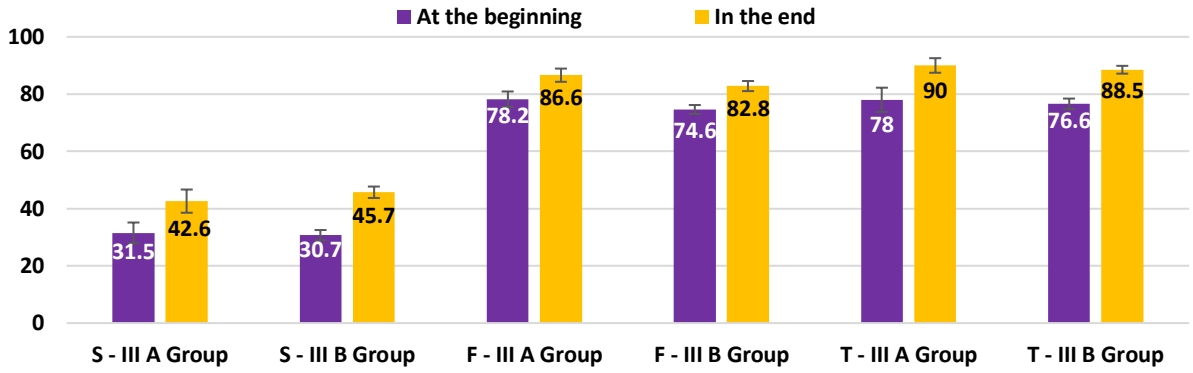



***Fig. 26 Results of the "Pelvic Oscillation" study at the beginning and end of the observation period in patients from groups III$^{A}$ and III$^{B}$***

### *3.5. Results of the study on "Symmetry Index"*

Table 16 presents the statistical data for the "Symmetry Index," recorded as a percentage (normal range 90-100%) for each individual parameter, at the beginning and end of the observation period for patients in groups III$^{A}$ and III$^{B}$ (p<0,05).

**Table 16 Statistical processing of the results of the "Symmetry Index" at the beginning and end of the observation period in patients from groups III$^{A}$ and III$^{B}$**

| Indicator | n | At The Beginning | | | | In The End | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{X}$ | SD | $C_v$% | CI 95% | $\bar{X}$ | SD | $C_v$% | CI 95% | t-test | p |
| **SI – III$^{A}$** | 35 | 69,0 | 10,421 | 15,1 | 65,4÷72,6 | 84,2 | 8,910 | 10,6 | 51,2÷87,3 | -6,164 | =0,000 |
| **SI – III$^{B}$** | 23 | 61,7 | 9,393 | 15,2 | 57,9÷65,5 | 76,8 | 7,637 | 9,9 | 73,7÷79,9 | -5,859 | =0,000 |

The SI combines multiple gait characteristics and most accurately demonstrates the presence of asymmetry in gait. Figure 27 reflects the results of the SI study for patients in groups III$^{A}$ and III$^{B}$ at the beginning and end of the observation period. At the beginning of the study, a value of 69% was recorded for patients with malleolar fractures (group III$^{A}$), while for those in group III$^{B}$, a value of 61,7% was observed, reflecting a more impaired gait in patients with complications (p=0,000). At the end of the observation, patients with malleolar fractures showed recovery (84,2%) close to the lower boundary of the normal range, while patients with complications reached 76,8%. The incomplete recovery of the SI is most likely due to residual pain, limited range of motion in the ankle joint, and muscle hypotrophy.

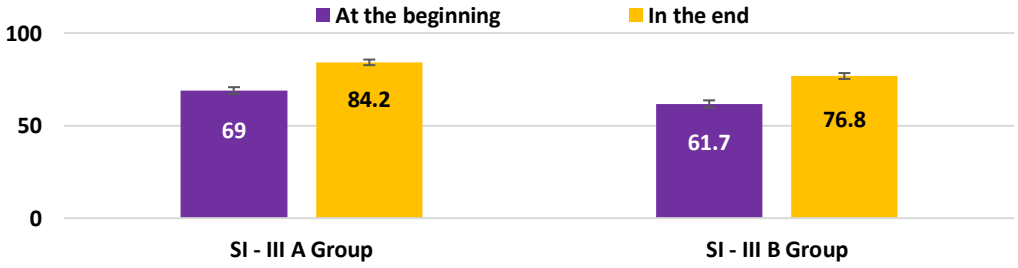



***Fig. 27 Results of the "Symmetry Index" at the beginning and end of the observation period in patients from groups III$^{A}$ and III$^{B}$***

## 4. Comparative analysis of the results between the groups

### *4.1. Results from the Visual Analogue Scale (VAS)*

Figure 28 shows that, at the beginning of the study, the lowest pain levels according to the VAS were reported by patients in group $I^B$, while the highest levels were recorded in those with CRPS complications. By the end of the study, this trend remained consistent, with patients in group $III^B$ still experiencing moderate pain during walking (score of 8,7).

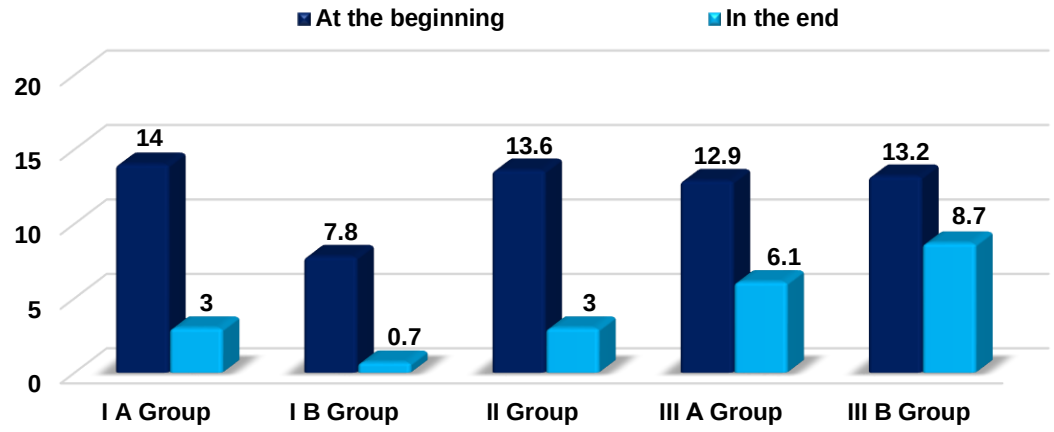



***Fig. 28 Results of the VAS for the initial and final assessments in all groups***

### *4.2. Period of recovery of locomotor activity*

The period required for the recovery of independent locomotor activity, as shown in Figure 29, is closely related to the intensity of pain, which determines its duration (from the time of injury to walking with assistive devices). The shortest recovery period was observed in patients who underwent ACL reconstruction, although their complete functional recovery required more time. The longest recovery period was noted in patients with CRPS complications.

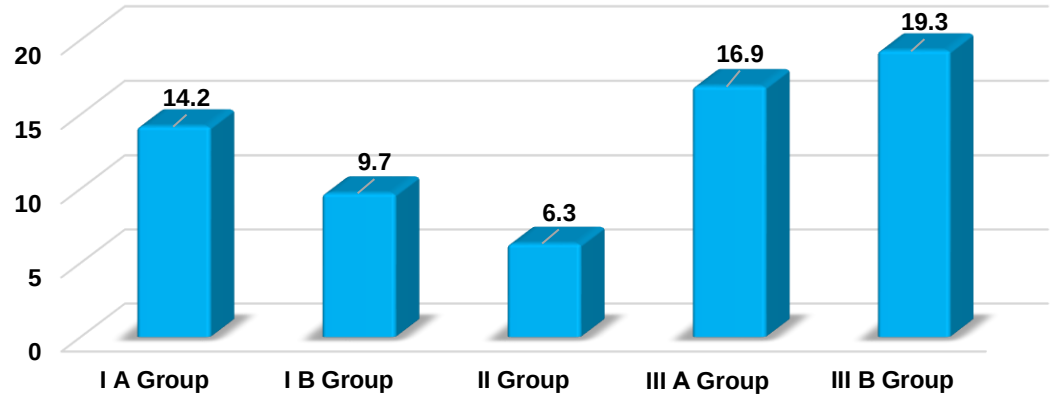



***Fig. 29 Recovery period of locomotor activity in the different groups, measured in weeks***

### *4.3. Results from the study of the "Stance Phase"*

The data from Figure 30 regarding the SP of the healthy limb show that patients with HJ injuries were within the normal range both at the beginning and end of the

study (established as 57–61% in percentage terms), whereas the most significant deviations were observed in those with AFC injuries.

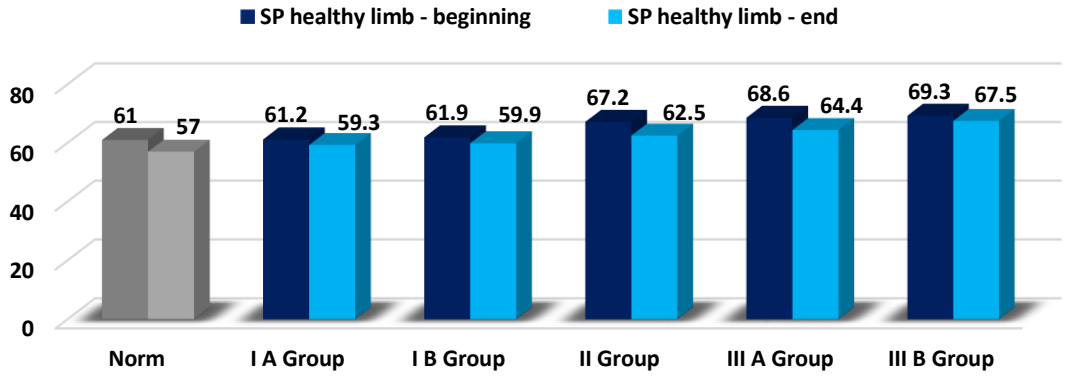



*Fig. 30 Results of the SP analysis for the healthy limb in %*

Figure 31, which presents the results for the SP of the injured limb, shows that only patients with AFC injuries remained below the lower limit of the normal range. The most significant improvement was observed in patients who underwent ACL reconstruction.

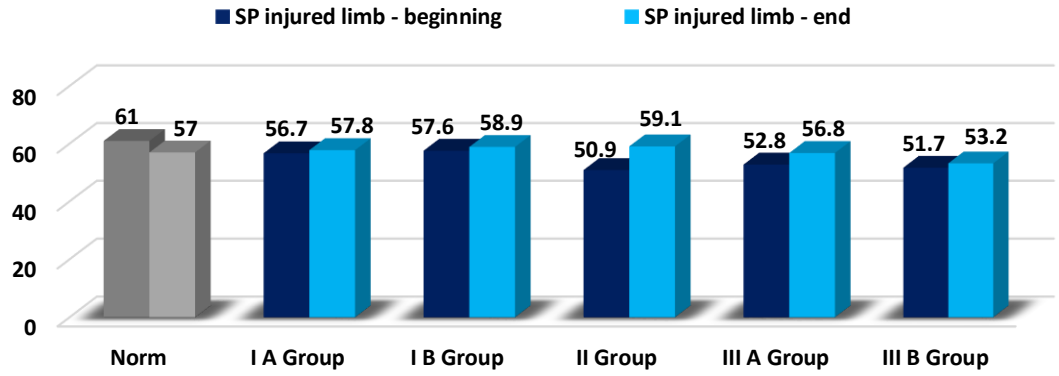



*Fig. 31 Results of the SP analysis for the injured limb in %*

### *4.4. Results from the "Single Support" analysis*

The graph in Figure 32 for SS of the healthy limb shows that patients with HJ injuries at the beginning and end of the study did not significantly differ from the normal range (41,4–36,3%), whereas the most substantial deviations were observed in patients with AFC injuries and those who underwent ACL reconstruction.

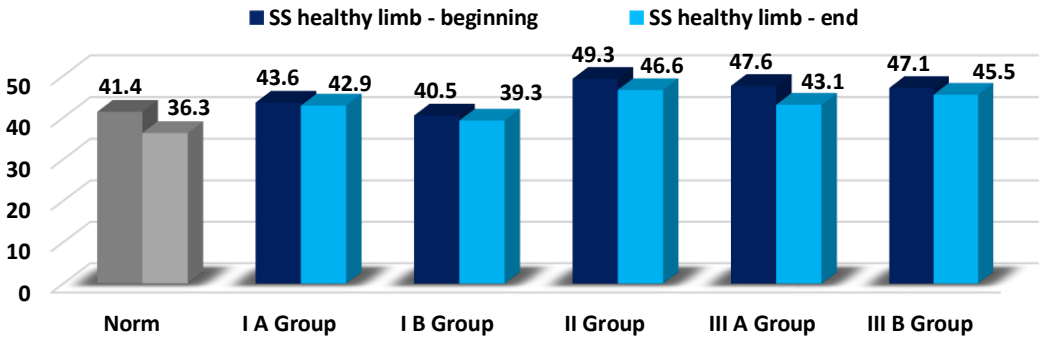



*Fig. 32 Results of the SS phase analysis for the healthy limb in %*

The data from Figure 33 for SS of the injured limb show that only patients with AFC injuries remain below the lower limit of the normal range.

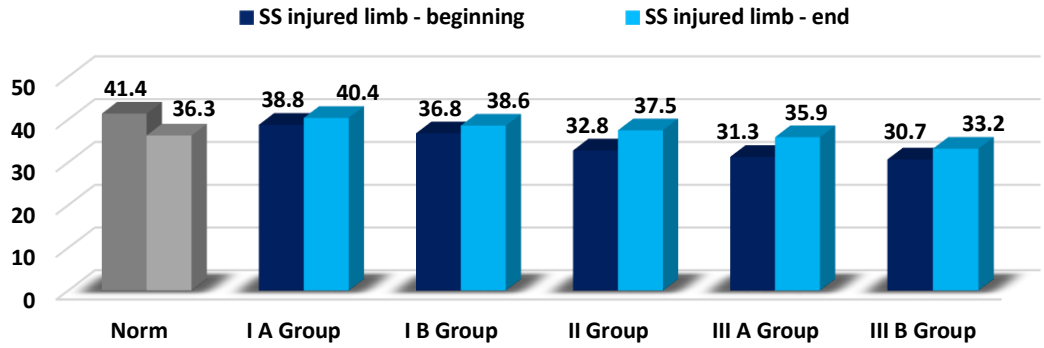



***Fig. 33 Results of the SS phase analysis for the injured limb in %***

### *4.5. Results from measuring gait "Cadence"*

Figure 34 reflects the results from the gait cadence assessment, with the normal range being around 115 steps/min. At the beginning of the observation period, lower values are recorded in patients with OM on hip joint. By the end of the period, the results closest to the norm are observed in patients with ACL reconstruction. The values furthest from the norm remain in the group with HJ arthroplasty.

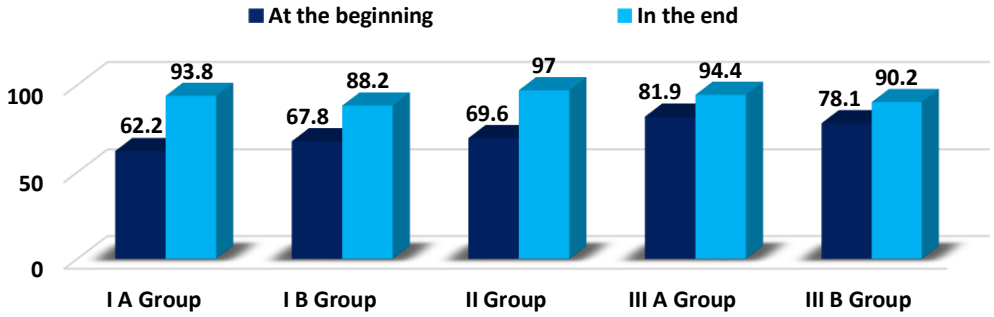



***Fig. 34 Results of gait "Cadence", measured in steps per minute***

### *4.6. Results from measuring gait "Speed"*

The initial results from the study of gait speed (m/s) on flat terrain (Figure 35) logically show the lowest values in patients with trauma to the HJ. By the end of the observation period, the highest walking speed is recorded in patients who underwent ACL reconstruction, while the values in the remaining groups show no significant differences.

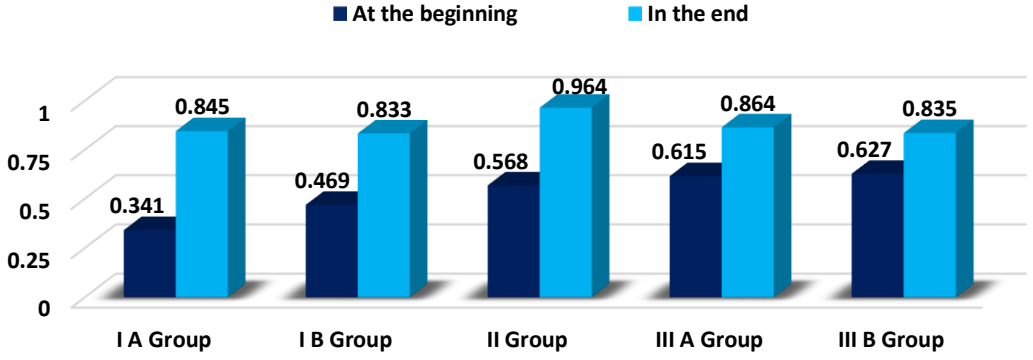



***Fig. 35 Results of gait "Speed" on* flat terrain, *measured in m/s***

At the beginning of the observation period, there is no significant difference in the speed of stair ascent among the different groups (Figure 36). By the end of the period, the highest average values are recorded in patients with ACL injury, while the lowest are found in those with a HJ fracture.

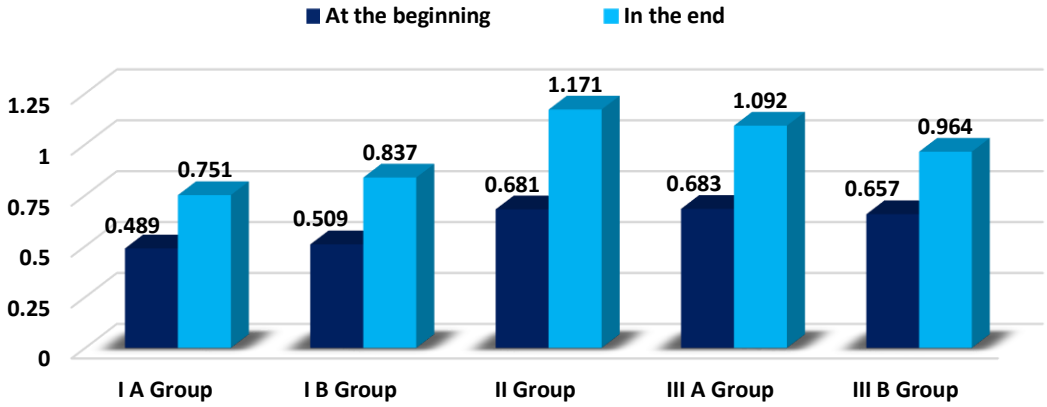



*Fig. 36 Results of gait "Speed" during ascent of stairs, measured in m/s*

At the beginning of the study, significantly lower results are recorded in elderly patients ($I^A$ and $I^B$ groups) for stair descent, as shown in Figure 37. The final results indicate that stair descent does not present difficulties for patients with ACL reconstruction, as they show the most significant improvement.

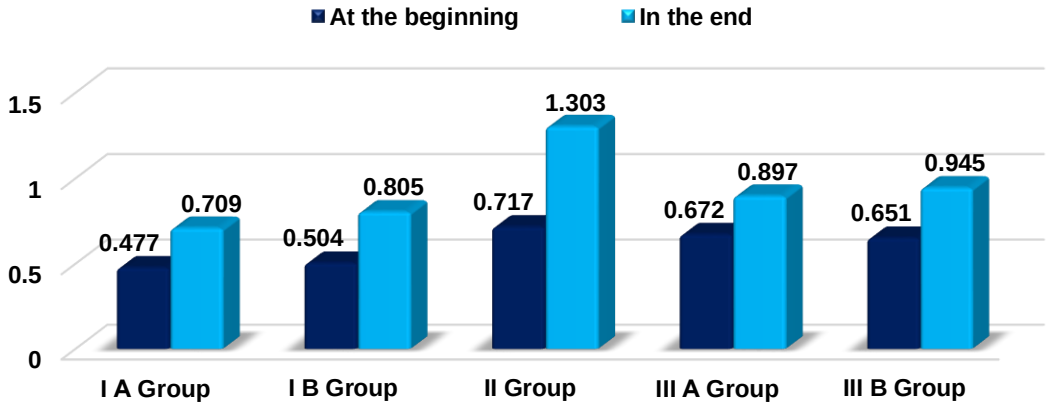



*Fig. 37 Results of gait "Speed" during descent of stairs, measured in m/s*

### *4.7. Results of "Pelvic Oscillation" in different planes*

For pelvic oscillations in the sagittal, frontal, and transversal planes, norms in percentage (90-100%) were established.

When comparing the results of pelvic oscillations in the sagittal plane, it is noticeable that the values of older patients are significantly better at the beginning and end of the observation period compared to those in the other groups, as shown in Figure 38. The baseline results for patients with CRPS complications are unsatisfactory. At the end of the study, the values for injuries in the ankle and knee joints, typical for younger individuals, are about 1/3 lower than those of the older patients.

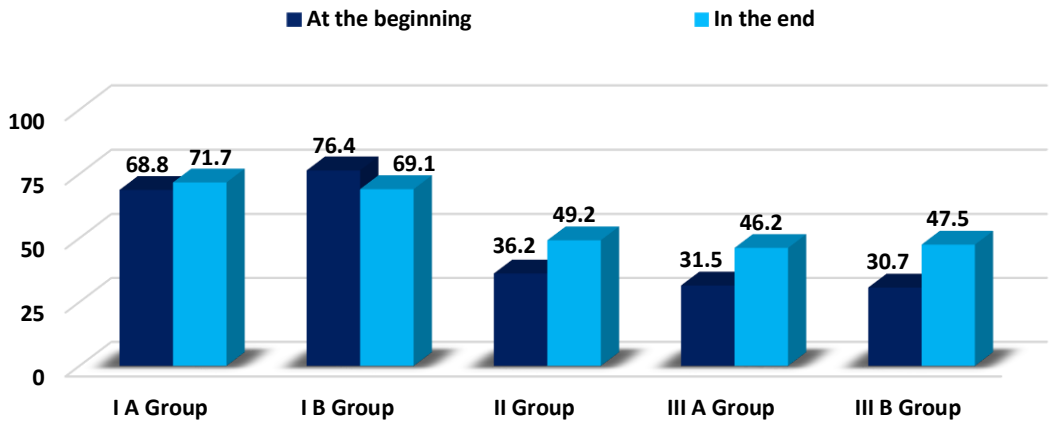



***Fig. 38 Results of "Pelvic Oscillation" in the sagittal plane, presented in %***

The baseline results for pelvic oscillations in the frontal plane are shown in Figure 39 and indicate lower values in patients with HJ trauma, while the other groups show similar initial values. At the end of the observation period, the recovery of patients with ACL reconstruction is the most significant and falls within the normal range. The lowest values at the end of the observation are recorded in the older patients, despite their most significant improvement.

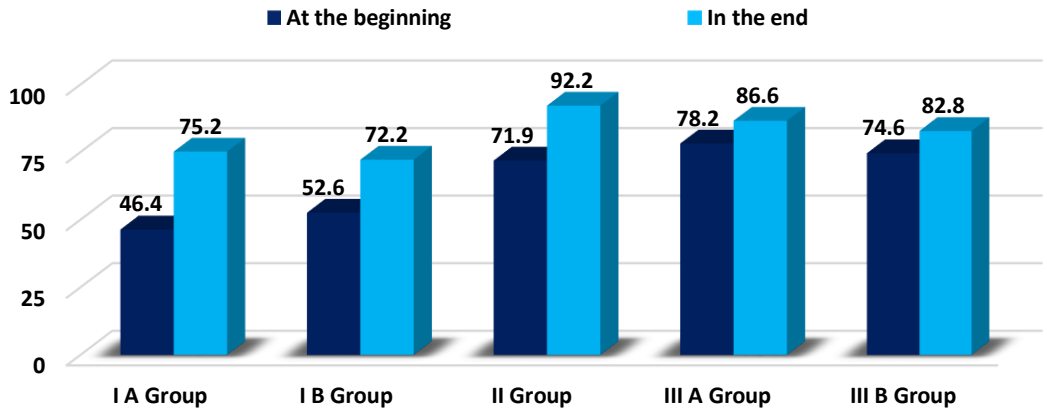



***Fig. 39 Results of "Pelvic Oscillation" in the frontal plane, presented in %***

In the study of pelvic oscillations in the transversal plane, identical values are observed compared to those in the frontal plane, with a similar interpretation of the obtained results – Figure 40. At the beginning of the study, the values for patients with HJ trauma are the lowest, while the results for the other groups are similar. At the end of the observation period, patients with ACL reconstruction reach results that are at the lower limit of the normal range, while the values for the other groups equalize.

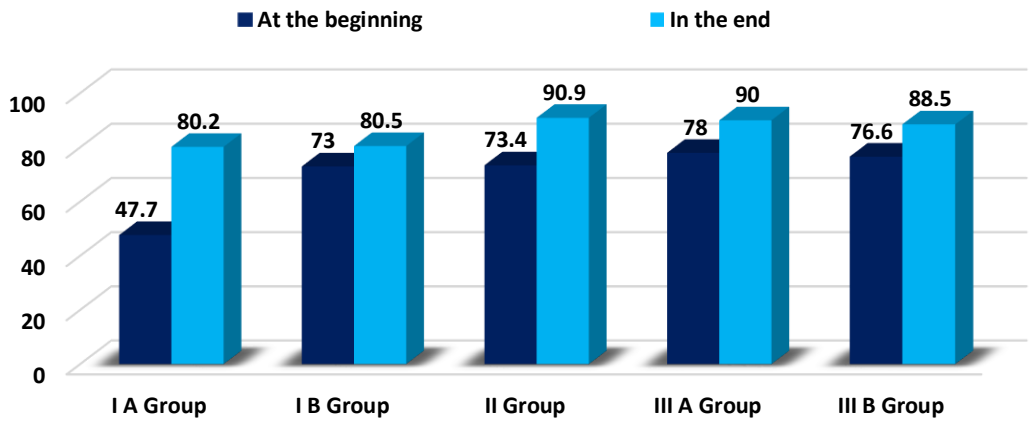



*Fig. 40 Results of "Pelvic Oscillation" in the transversal plane, presented in %*

### *4.8. Results from the "Symmetry Index" of gait*

At the beginning of the study, patients with CRPS complications exhibited the most asymmetrical gait, which remained unchanged at the end of the observation period (Figure 41). Patients with malleolar fractures had better initial and final results, while elderly patients with HJ trauma did not show significant improvement by the end of the study, as their initial values were already sufficiently high. The best result at the end of the observation period, reaching the lower limit of the normal range, was observed in patients with ACL reconstruction.

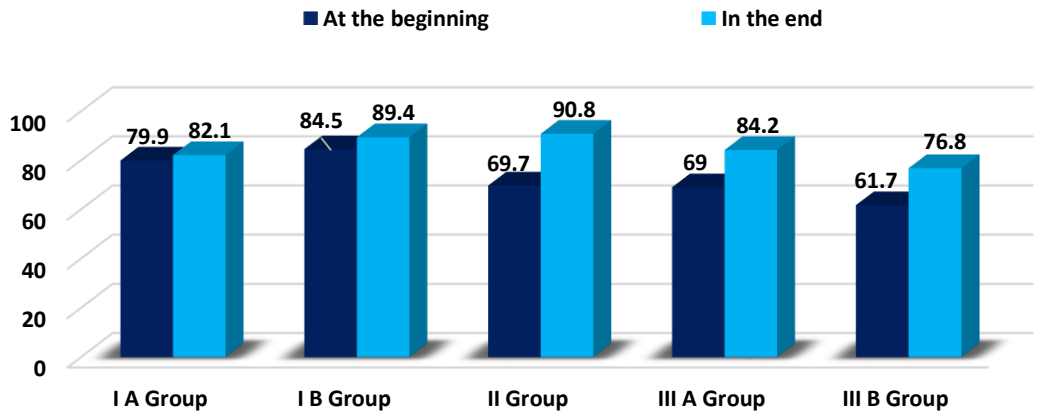



*Fig. 41 Results of the "Symmetry Index" of gait, presented in %*

## 5. Results from the Functional Tests conducted

### *5.1. Results from the "Activities of Daily Living" test*

The study investigates the ability of patients with lower limb trauma to perform Activities of Daily Living (ADL), determined by the need to engage in locomotor activity with assistive devices over a certain period of time. Considering the nature of the different ADL groups and the wide variety of self-care activities, we conclude that the results should be analyzed in relation to the age and sex of the patients, rather than the location of the trauma. These criteria determine the distribution of patients by age and gender into four groups as follows: women under 65 years of age (39);

women over 65 years of age (33); men under 65 years of age (51); and men over 65 years of age (16), which are graphically represented in Figure 42.

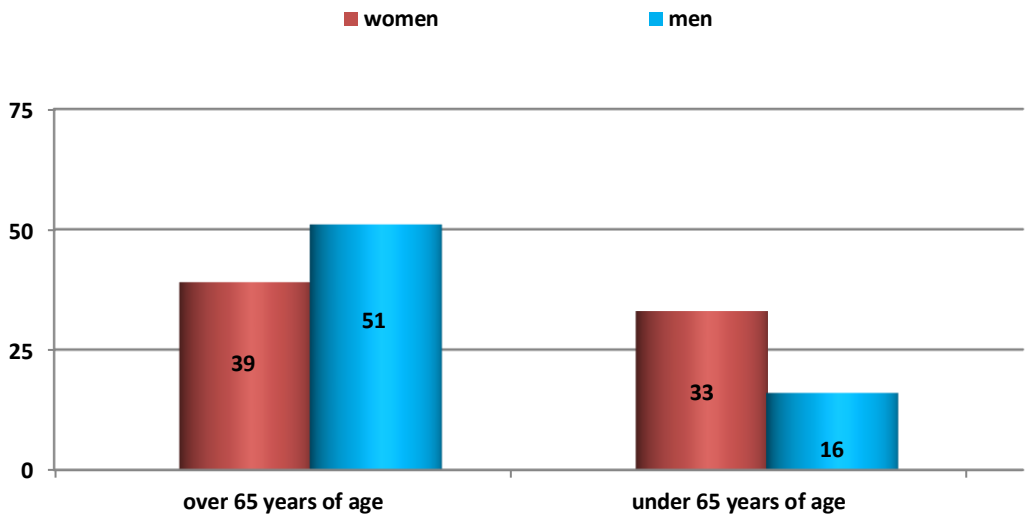



***Fig. 42 Distribution of all patients included in the study according to the characteristics "age" and "gender"***

The mean arithmetic values of the results from the ADL test for patients with impaired locomotor function at the beginning and end of the study are presented in Table 17.

**Table 17 Mean arithmetic values from the ADL test at the beginning and end of the observation period in the different groups**

| Indicator/ Degree | Women under 65 y. | | Women over 65 y. | | Men under 65 y. | | Men over 65 y. | |
|---|---|---|---|---|---|---|---|---|
| | Beginning | End | Beginning | End | Beginning | End | Beginning | End |
| Visiting the toilet | 1,72 | 2,67 | 1,40 | 2,48 | 1,8 | 2,91 | 1,21 | 2,39 |
| Maintaining personal hygiene | 1,89 | 2,67 | 1,40 | 2,40 | 1,89 | 2,86 | 1,21 | 2,36 |
| Dressing and putting on shoes | 1,72 | 2,58 | 1,43 | 2,43 | 1,84 | 2,86 | 1,14 | 2,32 |
| Food preparation | 1,64 | 2,61 | 0,83 | 2,23 | 1,11 | 2,64 | 0,36 | 2,25 |

The graphical representation of the results is shown in Figure 43. The baseline values for the questions related to self-care (visiting the toilet, maintaining personal hygiene and dressing and putting on shoes) for patients in all groups are identical. As expected, both men and women under 65 years old have better values (from 1,72 to 1,89) than the older patients (from 1,14 to 1,43). Respectively, at the end of the study, after the removal of walking aids and independent mobility, the maximum functional recovery for performing daily activities related to self-care is observed. For women under 65 years old, these values are 2,67 for visiting the toilet and maintaining personal hygiene; 2,58 for dressing and and putting on shoes and for men – 2,91 for visiting the toilet and 2,86 for maintaining personal hygiene and dressing and and putting on shoes. The values for the three self-care activities in patients over 65 years old show minimal differences,

respectively – 2,40; 2,43; 2,48 for women and 2,32; 2,36; and 2,39 for men. The mentioned data lead to the conclusion that by the end of the observation period, all patients are able to perform daily activities related to self-care independently. Activities related to “food preparation” in patients under 65 years old were rated with lower scores compared to self-care capabilities, with baseline scores of 1,64 for women and 1,11 for men. These values are significantly lower in patients over 65 years old – 0,83 for women and 0,36 for men. At the end of the study, the values for women in both age groups (2,61 and 2,64) understandably approach independent execution of food preparation activities, while men’s values remain closer to the level “need for assistance” (2.23 for those under 65 years old and 2,25 for those over 65 years old). These results may be attributed to the fact that, in order to prepare food, one first needs to secure food products, which require locomotor activity outside the home. Additionally, the activity of “food preparation” is, in human cultural psychology, primarily associated with women.

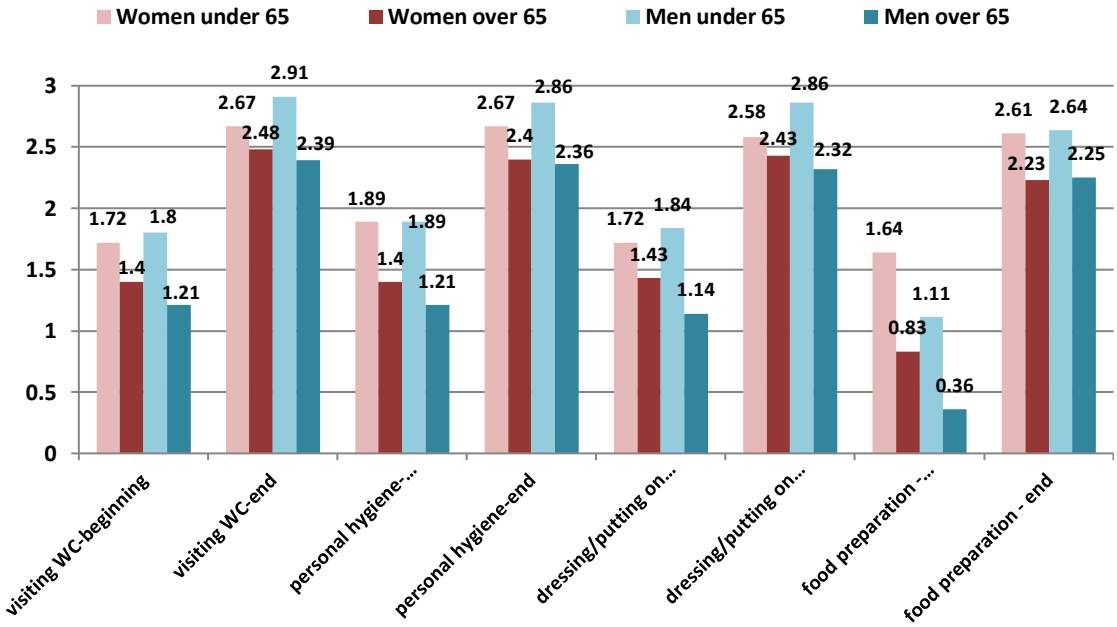
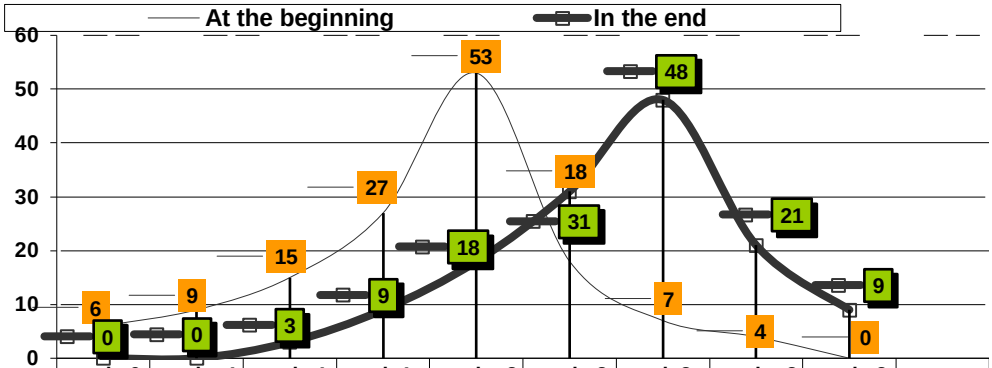



***Fig. 43 Ability to perform ADL at the beginning and end of the observation period in patients from different groups***

Self-care activities, such as "visiting service rooms" "maintaining personal hygiene" "dressing and and putting on shoes" and "food preparation" were initially difficult to perform without assistance for 41,01% of all subjects included in the study. Independent performance of daily activities was observed in 51,08%, though for some tasks, external help was still needed. Only 7,91% were completely independent in daily activities. At the end of the study, these proportions shifted in favor of independent and self-sufficient performance of daily activities (78,41%), as demonstrated by the Wilcoxon curve (Figure 44), which shifts to the right, indicating favorable recovery. The lower values on the scale remain for 21,59% of all patients, due to older age and the presence of multiple comorbid conditions, which slow down and hinder functional recovery of locomotor activity and, consequently, self-care.




| | grade 0 | grade -1 | grade 1 | grade1+ | grade -2 | grade 2 | grade2+ | grade -3 | grade 3 |
|---|---|---|---|---|---|---|---|---|---|
| At the beginning | 6 | 9 | 15 | 27 | 53 | 18 | 7 | 4 | 0 |
| In the end | 0 | 0 | 3 | 9 | 18 | 31 | 48 | 21 | 9 |

***Fig. 44 Wilcoxon curve for the results of the ADL test for all studied patients at the beginning and end of the observation period***

### *5.2. Results from the "Locomotor Activity" test*

The aim of this study is to examine the recovery of locomotor activity in patients after lower limb trauma, which is related to the ability to move independently and perform daily activities. The results from the "Locomotor Activity" test justify the classification of all patients included in the study into two age groups, as no significant differences are observed based on gender. Figure 45 shows the results obtained at the beginning and end of the observation period for two age groups: under 65 years (90 patients – 39 women and 51 men) and over 65 years (67 patients – 33 women and 16 men). Since one of the inclusion criteria for the study was the need to perform locomotor activity using two crutches, the initial average values for both age groups are close to 3 points ("walking with two crutches"). However, the value for the older age group is slightly lower (2,59 points) compared to the younger age group (3,68 points). At the end of the study, all patients can move independently without assistive devices. Patients in the younger age group approach normal physical activity levels when walking (13,74 points), while older patients still require the use of a cane for walking longer distances (12,35 points).

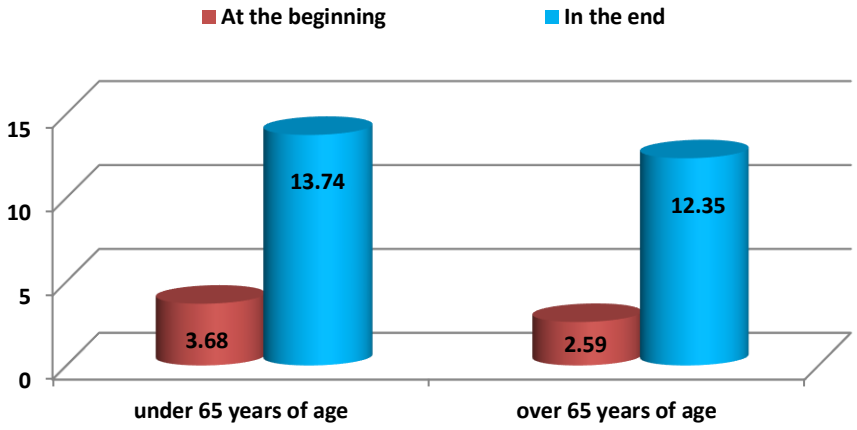



***Fig. 45 Results of the "Locomotor Activity" test for patients from the two age groups at the beginning and end of the observation period***

## 6. *Results from the "Standardized Interview"*

A standardized interview was conducted on a voluntary basis with all 139 patients, aged 19 to 88 years, of whom 72 were women and 67 were men. This method of sociological research allows for direct communication with the patients, providing them with the opportunity to express their opinions regarding the questions related to their social functioning after lower limb trauma. For the purpose of the scientific study, a standardized questionnaire was developed, which included five groups of questions: 1) the ability to move through the environment with assistive devices; 2) the ability to perform daily household and work activities; 3) the ability to socially function with impaired locomotor activity; 4) the ability to use transport services; 5) emotional states of anxiety.

The patients' opinions are presented on a four-point scale: degree 0 – "the participant cannot perform the given activity"; degree 1 – "the participant attempts the activity but has no functional outcome"; degree 2 – "the participant performs the activity, but a companion is needed to observe, control, and guide the patient" and degree 3 – "the participant performs the activity normally, efficiently, and completely independently". To analyze the results, the patients are once again grouped by "gender" and "age." The responses of the participants are presented as average values for each group, for each question within the group, and for the entire set of questions. The analysis of the results of the study is expressed in the presentation of: quantitative analysis of the relative frequency (in average arithmetic value) of the patients' responses; qualitative analysis for possible causes, dependencies, trends, etc.

The results of the answers to the group of questions related to the possibility of using transport services are presented in Table 18.

**Table 18 Average arithmetic values from the group of questions "Possibility of Using Transport Services" at the beginning and end of the observation period in the different groups**

| Indicator/ Degree | Women under 65 y. | | Women over 65 y. | | Men under 65 y. | | Men over 65 y. | |
|---|---|---|---|---|---|---|---|---|
| | Beginning | End | Beginning | End | Beginning | End | Beginning | End |
| Self-driving | 1,03 | 1,75 | 0,63 | 1,28 | 1,30 | 2,80 | 0,71 | 1,89 |
| Using public transport | 1,19 | 2,31 | 0,68 | 2,00 | 1,27 | 2,66 | 0,89 | 2,29 |
| Car use | 1,50 | 2,56 | 1,03 | 2,38 | 1,64 | 2,81 | 0,93 | 2,54 |

The results from the group of questions focused on the ability to use transportation vehicles among patients with lower limb trauma and impaired locomotor activity, presented in Figure 46, show the lowest values in terms of independently driving a car. These values are consistent regardless of age and gender but are determined by post-fracture motor limitations of the lower limbs (1,03; 0,63; 1,3; 0,71). It is important to note here that not all of the surveyed patients are licensed or capable of independently operating a motor vehicle (car). As a result of the implemented rehabilitation program and improved locomotor activity, male patients under the age of 65 show the highest level of improvement – score 2,8 out of a maximum of 3. The greatest difficulty reported across all groups is the use of public transport (1,19; 0,68; 1,27; 0,89), mainly due to crowding at stops, limited time to

board and disembark, the presence of steps (even though some vehicles are equipped with platforms for ground-level boarding), and issues with public infrastructure. Final results indicate an improvement of over 1 degree, particularly for men in both age groups and women under 65, while for women over 65 years, the improvement reaches level 2. The ability to use automobile transport across all age groups shows higher values both at baseline (1,5; 1,03; 1,64; 0,93) and at the end of the observation period (2,56; 2,38; 2,81; 2,54).

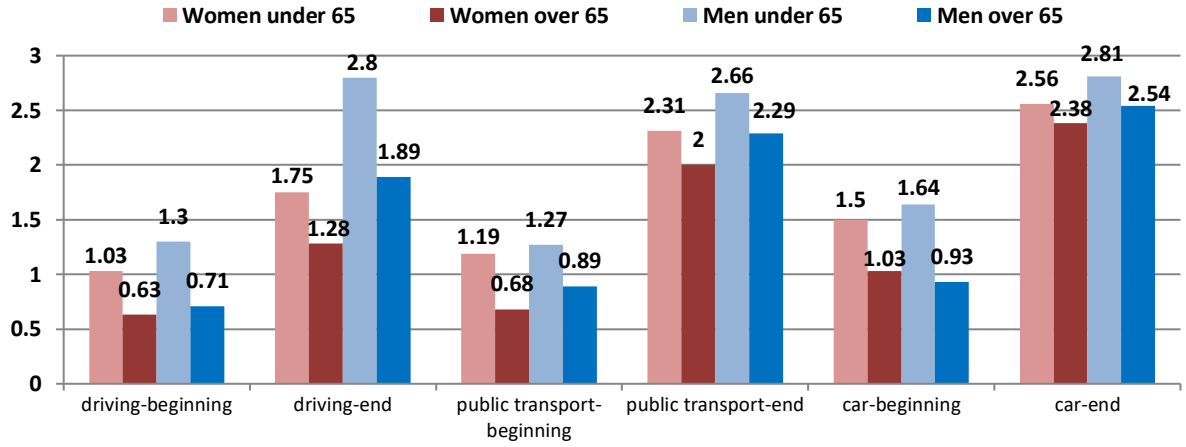



***Fig. 46 Results from the group of questions "Ability to use transportation" at the beginning and end of the observation period***

The results from the responses to the questions related to the onset of emotional anxiety caused by the trauma are presented in Table 19.

**Table 19 Results from the group of questions on "Emotional Anxiety" at the beginning and end of the observation period across the different groups**

| Indicator/ Degree | Women under 65 y. | | Women over 65 y. | | Men under 65 y. | | Men over 65 y. | |
|---|---|---|---|---|---|---|---|---|
| | Beginning | End | Beginning | End | Beginning | End | Beginning | End |
| Independence in ADL | 1,39 | 2,58 | 1,18 | 2,33 | 1,52 | 2,70 | 1,36 | 2,43 |
| Achievement of planned activities | 1,47 | 2,64 | 1,08 | 2,28 | 1,43 | 2,73 | 1,16 | 2,17 |
| Precision in performing activities | 1,44 | 2,61 | 1,00 | 2,18 | 1,43 | 2,66 | 1,04 | 2,19 |

As a result of trauma, it is normal for any person to experience a state of emotional anxiety. The results of this aspect of the study are presented in Figure 47. Following lower limb trauma and impaired ability to move through the environment, this greatly affects the individual's entire life and hinders the performance of daily professional and household activities (1,39; 1,18; 1,52; 1,36), which require more time and often the assistance of another person. Identical results were observed in the other two questions reflecting the emotional state of patients when unable to complete planned daily tasks and when precision in desired activities was impaired. After the rehabilitation program – during which the ability to walk without assistive devices was restored – feelings of anxiety were overcome. Patients (both women and men) under the age of 65 demonstrated greater independence and precision in

carrying out planned activities. Their results exceeded 2,5 on a maximum scale of 3. Lower values were observed in patients over the age of 65, due to age-related anxiety conditions, which are associated with their overall health status.

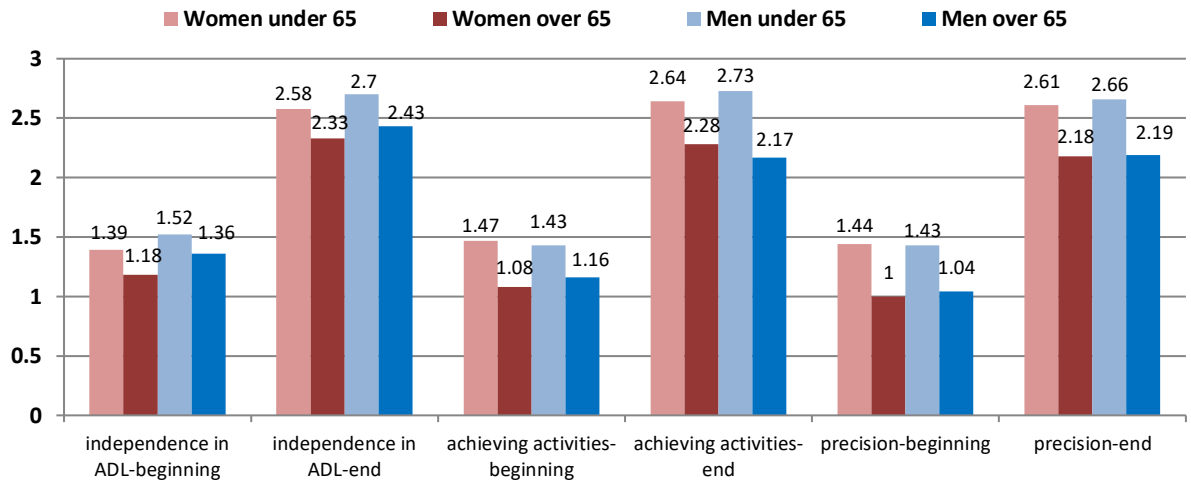



***Fig. 47 Results from the questions on "Emotional states of anxiety" in patients with impaired locomotor activity at the beginning and end of the observation period***

As a result of the applied comprehensive medico-social program aimed at overcoming the negative aspects of limited locomotor activity, significant improvement was observed in the motor activity of patients when performing activities of daily living. All of this stimulates their social engagement, reduces the level of anxiety, and leads to an improvement in their quality of life. Although the recovery process is slow and prolonged, the results provide sufficient grounds to conclude that the efforts of the multidisciplinary team contribute to overcoming the negative impacts on the social functioning of patients following lower limb trauma.

## DISCUSSION

The conducted analysis of the recorded results from the study, with a high degree of significance, provides grounds for drawing conclusions and making inferences regarding the recovery of locomotor activity, and more specifically, gait parameters in patients following lower limb trauma. Taking into account the large volume of gathered data and the number of assessed criteria, the discussion focuses on the following indicators: VAS for pain; stance and single phase of gait; walking speed on flat terrain and when ascending/descending stairs; pelvic motion in the sagittal, frontal, and transverse planes; symmetry index, as well as the time required to regain independent spatial mobility without assistive devices.

**Pain** is a leading and essential symptom in all post-traumatic conditions and is a determining factor for conducting an optimal rehabilitation program. According to the VAS results at the end of the observation period, a reduction in pain intensity was observed across all patient groups. A “missing or mild level” of pain (score 0,7) was reported only by patients who underwent hip joint arthroplasty. Patients from groups $I^A$ and II reported a score of 3, which also falls within the “absent or mild pain” category. The highest pain levels were recorded in patients with trauma to the AFC,

with a score of 6,1 in group $III^A$ and 8,7 in group $III^B$, indicating “moderate pain during walking.” Although full weight-bearing on the injured limb was permitted for these patients at a certain stage, those in group $III^B$ showed no functional recovery. It is necessary to conduct a comprehensive rehabilitation program over several consecutive courses, including analgesic procedures using preformed physical factors, as well as specialized kinesiotherapy techniques aimed at managing pain.

In addition to being a key factor in conducting a rehabilitation program, pain is also a determinant of the duration of the **recovery period of locomotor activity** in patients following lower limb trauma. Analysis of the results from the current study revealed that the longest recovery period (in weeks) was observed in patients from group $III^B$ (19,3 weeks). These findings are consistent with data in the scientific literature regarding the nature of the condition and the predominant pain syndrome, which indicates that recovery after trauma to the AFC can take from six months to one year, with the most significant improvement occurring during the first six months post-injury. The duration of recovery for walking without assistive devices in group $III^A$ was 16,9 weeks, followed by group $I^A$ (14,2 weeks). In both groups, the patients had fractures, which require a certain regenerative period for bone healing, thereby necessitating a longer period of non-weight-bearing. For patients with arthroplasty (group $I^B$), 9,7 weeks were needed for full weight-bearing on the limb. The shortest period of walking with assistive devices was recorded in patients who underwent ACL reconstruction – 6.3 weeks but full functional recovery in such cases requires 6 to 12 months, according to literature data. In our study, it was also found that at the time assistive devices were discontinued, patients still exhibited limited range of motion in the knee joint in flexion (approximately 40º deficit), muscle hypotrophy in the thigh (approximately 2,5 cm), and cadence and pelvic tilt values in the sagittal plane below normal. This impairs locomotor activity and leads to gait asymmetry. To stimulate the functional recovery of the injured lower limb, an analytical kinesiotherapy program (targeted quadriceps exercises and isometric contractions) is recommended to overcome muscle hypotrophy, along with electrical stimulation of the quadriceps femoris muscle.

One of the main gait parameters is the ratio between the **stance phase** and the swing phase, which is crucial for the gait cycle. The values of these two phases add up to 100%, meaning that if the SP of the healthy limb is greater, it will be correspondingly smaller for the injured limb. Similarly, when the SP of one limb is longer, the SW of the opposite limb is also longer. Established normative values for the human gait cycle indicate that the SP ranges between 57 – 61%, and the SW between 36,5 – 43,6%. The final results in the present study regarding the SP of the healthy limb among patients in the different groups show that those with trauma in the HJ area fall within the normal range (59,3% and 59,9%), despite being in the older age group. This suggests that locomotor activity is being carried out without pelvic asymmetry. In patients with ACL reconstruction, this parameter slightly exceeds the upper normative limit (62,5%), which means that the stance phase of the healthy limb is still longer at the expense of the injured one, indicating a slight gait asymmetry. The most deviation from the norm is observed in patients with AFC injuries –specifically after malleolar fractures (64,4%) and, even more so, in those

with the complication of CRPS (67,5%). Final measurements of the SP in the injured limb across all groups show recovery to normative values, except for patients in group $III^B$ (53,2%), where significant gait asymmetry (limping) persists. Only a minor deficit in SP is observed in patients with malleolar fractures (56,8%), though some asymmetry during walking is still present. The analysis of these results supports the conclusion that, in patients with injuries in the ankle-foot region, it is necessary to revise and optimize the rehabilitation program. The focus should primarily be on pain management using medication and appropriate therapy with preformed physical factors, as well as on restoring ankle joint range of motion. It is advisable to incorporate specialized techniques in the kinesitherapy regimen to improve dorsiflexion (e.g., post-isometric relaxation of the triceps surae muscle, manual techniques for ankle joint mobilization, and suitable lymphatic drainage massage of the lower leg).

A similar analysis applies to the results obtained from measuring the **single support phase**, which is closely related to the SP and is a key component of it. Across all patient groups, the values of SS for both the healthy and injured limbs improved by the end of the study. Some groups had initial results close to the normative range (36,3% – 41.4%). The end-of-study data for the healthy limb show that patients with arthroplasty (40,4%) and those with ACL reconstruction (40,6%) fall within the normative range. The values for patients with femoral osteosynthesis are also very close to the norm (42,9%), and this minimal deviation does not significantly impact gait. In the groups with injuries to the AFC, values of 43,1% for malleolar fractures and 45,5% for patients with the CRPS complication were observed. These elevated values are due to pain, leading to an increased SS in the healthy limb at the expense of the injured one. This results in what is known as an antalgic gait, which often persists even after assistive devices are removed. Habitual gait patterns are not uncommon and require a detailed kinesiological analysis, followed by the development of an appropriate analytical kinesitherapy program to overcome them. Achieving maximum functional recovery depends greatly on the patient's conscious and active participation in the healing process. The results for the SS of the injured limb show an inverse relationship – lower values indicate quicker transition through the SP and a tendency to avoid loading the injured limb. These findings mirror those of the healthy limb. Within normative values are the SS results of patients in the two hip trauma groups – 39,3% for MO and 38,6% for arthroplasty – as well as for those with ACL reconstruction (37,5%). Below-normal values were observed in the two AFC trauma groups: 35,9% in malleolar fracture patients and 33,2% in those with CRPS. Once again, the data highlights that CRPS has a significant impact on gait, even after assistive devices have been discontinued. These patients tend to transition more quickly through the SS of the injured limb, indicating substantial gait asymmetry (manifested as limping).

A key temporal characteristic of gait, recorded when walking with the inertial sensor, is **the speed** of movement through the environment. This parameter is automatically recorded and monitored during obstacle navigation such as climbing and descending stairs and an individual norm is determined based on the characteristics of the examined person, varying between 1,10 m/s and 1,40 m/s. The

results at the end of the study show similar average values in the groups of patients with injuries to the HJ and the (AFC), specifically 0,845 m/s, 0,833 m/s, 0,864 m/s, and 0,835 m/s. Only patients with ACL reconstruction show a higher movement speed (0,964 m/s), coming closer to the average norm, which is attributed to their younger age group. Another variant of the movement speed examination using the sensor device is the patients' ability to **overcome obstacles** such as climbing and descending stairs, which is inevitable in daily life. The study was conducted on 10 steps with a height of 20 cm, and it is important to note that these speed values should not be compared with walking speeds on level ground, as 10 steps do not equal 10 meters of distance. The speed for climbing stairs in the different groups at the end of the study ranged from 0,751 m/s to 1,171 m/s, with the highest average climbing speed observed in the patients from group II. Following them are the patients with injuries to the AFC, which can also be explained by the younger age characteristics of these patients. The lowest values for this parameter were observed in older patients with HJ trauma, with those having hip arthroplasty showing slightly better results compared to those with femoral osteosynthesis. This trend is also observed in the descending speed (0,709 m/s and 0,805 m/s). Descending stairs did not pose a challenge for patients with ACL reconstruction, as they did not experience restrictions in knee flexion, allowing them to step on the lower step with the healthy limb, which led to a higher descending speed (1,303 m/s) compared to other patients. Patients with AFC injuries demonstrated lower descending speeds than climbing, due to restricted dorsal flexion in the ankle joint required for stepping with the healthy limb onto the lower step, slowing down their speed. It should be noted that all people experience some sense of insecurity when navigating stairs, especially during descent. This is even more true for patients using assistive devices.

One of the gait characteristics, which is registered for the first time with the help of the inertial sensor (G-WALK) and allows for analysis of the obtained results, is the study of **pelvic oscillations** in the three planes – sagittal, frontal, and transversal, for which a norm of 90-100% has been established. When comparing the results of pelvic oscillations in the sagittal plane, it is noticeable that the values for older patients are better. Both at the beginning (group $I^A$ – 68,8% and group $I^B$ – 76,4%) and at the end (71,7% for group $I^A$ and 69,1% for group $I^B$) of the study, their results differ from the other groups. The pelvic asymmetry in the **sagittal plane** is caused by pelvic oscillations in the anterior-posterior direction, which in HJ trauma patients are not significant even in the initial measurements and remain almost unchanged by the end of the study. The analysis of the results gives reason to assume that these patients do not rely on assistive devices to offload the limb but instead load both limbs evenly. Hip fractures are severe injuries, often accompanied by bleeding in the hip joint area, and frequently, especially in older patients, the motor habit of walking is "disrupted" within a short period. Patients with ACL reconstruction already show an initial result of 36,2%, which improves to 49,2% by the end of the study. The lowest initial results are recorded in patients with CRPS (30,7%), and their final results are 47,5%. Similar results are seen in patients with malleolar fractures, with 31,5% initially and 46,2% at the end. The analysis of the results of pelvic oscillations in the **frontal plane** at the start (46,4% for patients with metal osteosynthesis and 52,6%

for those with arthroplasty) and the end (75,2% for group $I^A$ and 72,2% for group $I^B$) of the study shows that patients with HJ trauma exhibit asymmetry manifested as pelvic elevation and depression. This movement is performed with compensatory pelvic lifting to facilitate the SW of the injured limb instead of performing flexion in the HJ. In the initial results, lower values are observed in patients with MO due to more intense pain, but by the end of the study, both groups show similar values. However, the final results remain around ¼ of the norm, which is predetermined by the age characteristics of this group of patients. The most significant recovery (by 20,3%) in pelvic oscillations in the frontal plane is recorded in patients with ACL reconstruction (92,2%). The initial values for this characteristic of gait are 71,9%, which is a result of the brace used to limit flexion in the KJ and the need for compensatory pelvic lifting to initiate the swing of the injured limb. Due to shorter periods of using assistive devices and the younger age of these patients, their recovery falls within the normal range (90-100%). The results of pelvic oscillations in the frontal plane in patients with injuries to the AFC are similar at the start (78,2% for malleolar fractures and 74,6% for CRPS) and at the end (86,6% for group $III^A$ and 82,8% for group $III^B$). In these groups, recovery is minimal, as the initial results are the highest, and the observed pelvic asymmetry during walking is minimal compared to the other patient groups. The third plane of pelvic oscillation studied is the **transversal plane**, where identical values are observed compared to the frontal plane, with a similar interpretation of the obtained data. The pelvic oscillation in this plane is expressed as the asymmetrical ventral displacement of the iliac part of the pelvis along with the swinging limb. At the beginning of the study, patients with MO show the lowest values (47,7%), compared to patients in group $III^B$ (73,0%), which is again considered to be due to stronger pain. However, by the end of the study, these values align (80,2%) with those of the group with arthroplasty (80.5%). This characteristic of gait in older patients does not fully recover to normal levels, highlighting the need for attention to correct walking with the knee raised forward on the swinging limb, instead of relying on the pelvic rotation with the same-side iliac bone. The initial results (73,4%) in patients with ACL reconstruction show lower values, which again is due to partial immobilization in the joint from the use of a brace. By the end of the observation, these patients reach values (90,9%), which are at the lower end of the normal range. Groups with injuries in the AFC show similar initial values, with 78,0% for group $III^A$ and 76,6% for group $III^B$, and final results of 90,0% for malleolar fractures and 88,5% for those with CRPS complications. For patients with these injuries, it can be concluded that they recover at the lower boundaries of the normal range and when performing locomotor activities, exhibit no significant pelvic oscillations in the transversal plane.

The device software calculates all gait parameters obtained during the examination, summarizing the results in the so-called **Symmetry Index**, expressed as a percentage. This indicator provides a theoretical understanding of the smoothness and symmetry of gait when transferring weight from one limb to the other, with a standard norm of 90-100%. For the purposes of this study, it is important to analyze the SI at the beginning and end of the study in patients with different lower limb injuries. At the beginning of the study, patients with CRPS complications showed the worst gait (61,7%), which remained unchanged at the end

of the observation period (76,8%). Patients with malleolar fractures showed better results, with an initial value of 69% and a final value of 84,2%. Patients with ACL reconstruction had an initial value of 69,7%, but their final results fall within the normal range (90,8%). Older patients with HJ trauma did not show significant improvement in SI by the end of the study, as their baseline values were already quite high (79,9% for patients with MO and 84,5% for patients with arthroplasty). This feature can be explained by the age-related characteristics of the patients, who even while using assistive devices, tend to load both limbs evenly, especially those with arthroplasty. The final results showed a value close to the normal range (89,4%) for patients with arthroplasty and 82,1% for those with MO.

Based on the analysis of the results from the conducted study, it can be confidently stated that, by the end of the rehabilitation period, all patients examined perform locomotor activities without assistive devices. However, not all of them achieve maximum functional recovery in certain gait characteristics.

## FINDINGS

1. Based on the available scientific literature, it was concluded that the most suitable tool for the purpose of this study on locomotor activity (including gait parameters) is the G-WALK inertial sensor.
2. It was found that the applied research program for measuring locomotor activity using the G-WALK inertial sensor in patients after lower limb trauma was well received (it did not cause risky situations or incidents) and can be applied to study gait recovery after various lower limb injuries and diseases.
3. The evaluation of the results obtained at the end of the observation period shows that all measurements and tests have significantly better values, but not all patients show maximal functional recovery.
4. Specific and general indicators for the recovery of locomotor activity in patients after lower limb trauma are evaluated with high statistical significance, which confirms the working hypothesis and provides grounds for recommendations to create an appropriate comprehensive rehabilitation program.
5. The analysis of the results from the study on the recovery of locomotor activity after hip joint trauma shows that, despite advanced age (over 65 years), these patients fully recover their independent gait.
6. Patients with ACL reconstruction restore their gait parameters without assistive devices within the accepted norms, but their maximal functional recovery is delayed.
7. For patients with injuries to the ankle-foot complex, despite being in a younger age group, a high degree of regional pain is noted, which is characteristic of complex regional pain syndrome.
8. The summarized results from the standardized interview show that individuals with impaired locomotor activity experience certain medico-social problems, for which appropriate measures need to be proposed.

## RECOMMENDATIONS

1. The analysis of the results from the study on the recovery of locomotor activity after hip joint trauma shows that, despite the advanced age of these patients (over 65 years), they recover independent gait and require maintenance of optimal physical activity, supported by possible medico-social care.
2. Patients with knee joint reconstruction restore their gait without assistive devices within the accepted norms, but their maximal functional recovery is delayed, which requires the implementation of a prolonged and targeted rehabilitation program, with a focus on the kinesiotherapeutic component.
3. For patients with injuries to the ankle-foot complex, despite being in a younger age group, a high degree of regional pain, characteristic of Complex Regional Pain Syndrome (CRPS), is noted. Specialized, comprehensive pharmacological and physiotherapeutic treatment is required, including pain management and neurovegetative therapy, as well as appropriate electrotherapy procedures and kinesiotherapy techniques.

**CONTRIBUTIONS**

1. The conducted literature review systematizes classical and modern methods for examining and analyzing gait, contributing to the expansion of the theoretical and scientific foundation of kinesiotherapy.
2. An objective database has been created, which can be used by various specialists to study locomotor activity and to conduct kinesiological gait analysis in patients with different lower limb injuries.
3. A methodology for functional assessment has been developed, allowing optimal monitoring of gait recovery in patients with various lower limb injuries.
4. The introduced methodology for examining gait parameters using the G-WALK inertial sensor, supported by specialized software, enables the collection of detailed data on the main characteristics of gait in patients with different lower limb injuries and assesses the effectiveness of the applied treatment.
5. For the first time in our clinical practice, gait is evaluated using the "Symmetry Index" indicator, providing an objective idea of the smoothness and symmetry of walking in patients after traumatic lower limb conditions. This can form conclusions and provide recommendations for rehabilitation practice.
6. An investigational program for studying locomotor activity in patients after lower limb trauma or disease has been created and tested in practice, with the development of an Individual Profile, which reflects detailed information about the initial and final values of the studied parameters.
7. Results from studies of a significant number of patients with lower limb injuries have been published, and the analysis of these results confirms the importance of locomotor activity for the social functioning of the individual, as reported by a specially developed Questionnaire for conducting a standardized interview.

## CONCLUSION

The comparative analysis of the recovery of key parameters of gait, both temporal and spatial, supported by statistical processing of the results obtained at the beginning and end of the observation period in patients with lower limb injuries, is one of the few studies of its kind in the field of kinesiotherapy. The conducted study provides valuable information regarding the potential for recovery of locomotor activity, particularly gait parameters. The methodology for examining gait parameters using inertial sensors, supported by specialized software, allows for the collection of detailed data on the main characteristics of gait. The documentation created for this study for assessing gait recovery with and without the use of assistive devices, combined with pain assessment, goniometry, and measurement, can be successfully implemented in clinical practice by all specialists working in the fields of medical rehabilitation and kinesiotherapy.

From a methodological point of view, the assessment of the effectiveness of locomotor function recovery is determined by the initial and final measurements of patients, grouped by age and injury location. The study provides answers to questions about the significance of important clinical and prognostic factors such as age and gender of the patient, injury location, surgical approach for each injury, presence or absence of complications, and the need for assistance in self-care, which temporarily hinders daily life and the social functioning of the individual. These factors are essential for optimizing the rehabilitation program.

The analysis of the results obtained from the measurements, tests, and studies with high statistical significance demonstrates the recovery of locomotor function in patients following lower limb injuries. The characteristics of gait closest to normal were observed in patients with reconstruction of the cruciate ligament, followed by those with hip arthroplasty and metal osteosynthesis, in whom functional recovery was noted. The greatest difficulty in walking without assistive devices was observed in patients with malleolar fractures, particularly those with the complication of CRPS.

## LIST OF PUBLICATIONS
## ON THE TOPIC OF THE DISSERTATION WORK

1. Vacheva D., Petkova I., **Drumev A.** The need for the development of a project to provide a technical device that registers the gait parameters in patients with impaired locomotion. *Management and Education*, 2023; Volume 19 (6): 145-151. ISSN: 1312 – 6121 (MNR – Group G **= 10 points**)
2. Vacheva D., **Drumev A.** Gait parameters – research and analysis. In: Volova T., ed. *Proceedings from the Twentieth National Scientific Session for Students and Lecturers of the Medical College at the Medical University of Pleven*. Pleven: MU Pleven Publishing House, 2022, 6-15. ISBN: 978-954-756-301-8 (MNR – Group G **= 15 points**)
3. **Drumev A.**, Vacheva D., Gigov S., Vasilev E. Rehabilitation program for ankle joint contracture with complications of Complex Regional Pain Syndrome. In: Kamburova M., ed. *Proceedings from the Sixth Scientific Conference "Public Health: Challenges to the Health System"*, May 26-27, 2023 – Pleven, 350-358. ISBN: 978-954-756-335-3 (MNR – Group G **= 7.5 points**)

## SCIENTIFIC ACTIVITY

1. European Public Health Week, organized by the European Public Health Association (EUPHA) on the theme "Global Issues, Local Actions," May 23-26, 2023.
2. Sixth Scientific Conference, organized by the Bulgarian Scientific Society for Public Health, on the theme "Public Health: Challenges to the Health System," May 26-27, 2023, Pleven, Bulgaria.
3. International Scientific Conference, organized by "Prof. Dr. Asen Zlatarov" University – Burgas, on the theme "Education, Science, Economy, and Technologies," June 22-23, 2023, Burgas, Bulgaria.
4. International Scientific Conference, organized by the National Sports Academy "Vassil Levski," on the theme "Sport and Security," October 6, 2023, Sofia, Bulgaria.
5. Twenty-First National Scientific Session for Students and Lecturers "A Vision for the Future," October 27-28, 2023, Pleven, Bulgaria.
6. European Public Health Week, organized by EUPHA on the theme "Multidisciplinary Teamwork for Working with Children with Disabilities," jointly organized with the Center for Special Educational Support and Personal Development of Children with Disabilities "P. R. Slaveykov" – Pleven, May 16, 2024, Pleven, Bulgaria.
7. International Scientific Conference, organized by "Prof. Dr. Asen Zlatarov" University – Burgas, on the theme "Education, Science, Economy, and Technologies," June 20-21, 2024, Burgas, Bulgaria.
8. Seventh Balkan Scientific Conference, organized by USB – Blagoevgrad Branch, on the theme "Science – Education – Art in the 21st Century," October 24-25, 2024, Blagoevgrad, Bulgaria.
9. Jubilee Scientific Conference with International Participation on the 50th Anniversary of MU – Pleven, November 1-3, 2024, Pleven, Bulgaria.
10. Jubilee Scientific Conference on the 20th Anniversary of the Faculty of Public Health at MU – Pleven, November 1-3, 2024, Pleven, Bulgaria.

# RESEARCH ON LOCOMOTOR RECOVERY AFTER TRAUMATIC CONDITIONS OF THE LOWER LIMB


## ABSTRACT

**Introduction:** Walking is the primary means of human locomotion and a natural motor activity that enables the movement of the human body through the environment.

**Objective:** This study aims to investigate, monitor, and evaluate the recovery of gait parameters and locomotor activity in patients with post-traumatic conditions of the lower limb.

**Scientific Hypothesis:** Conducting a systematic scientific study of gait parameters will provide a valuable database for clinical practice, helping to identify specific patterns in the recovery of locomotor function after various traumatic lower limb conditions.

**Materials and Methods:** The study included 139 patients aged 19 to 88 years who met the criteria for trauma localization and the treatment being performed. (hip joint – osteosynthesis metallica and arthroplasty, knee joint – anterior cruciate ligament reconstruction, ankle joint – malleolar fractures and Complex Regional Pain Syndrome). Participants were categorized into two age groups (under and over 65 years) and had undergone physiotherapy and rehabilitation treatment at University Hospital “Dr. G. Stranski” – Pleven. To achieve the study's objectives, a comprehensive approach was used, incorporating functional assessments (VAS, centimetry, goniometry), statistical analyses (arithmetic mean, standard deviation, coefficient of variation, statistical error, confidence interval, and t-test with significance at $p<0,05$), and sociological methods (structured interviews and medical documentation review). Additionally, an advanced locomotor assessment methodology was applied, evaluating gait phases (stance phase and single-leg stance), cadence, walking speed on level ground and stairs, pelvic oscillations in the sagittal, frontal, and transverse planes, and symmetry index, utilizing the G-WALK inertial sensor.

**Results and Analysis:** Gait characteristics closest to the norm were observed in patients who underwent anterior cruciate ligament reconstruction, followed by those who had hip arthroplasty and osteosynthesis metallica treatment, indicating functional recovery. The greatest difficulties in walking without assistive devices were noted in patients with malleolar fractures, particularly those complicated by CRPS.

**Discussion:** Based on the analysis of the results, it can be reliably concluded that by the end of the rehabilitation period, all studied patients achieved independent locomotion without assistive devices. However, not all of them attained full functional recovery in specific gait characteristics.



**Keywords:** gait parameters, locomotor activity, lower limb trauma