IOSUD - "DUNĂREA DE JOS" UNIVERSITY FROM GALAŢI

Doctoral School of Social and Human Sciences

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GALATIENSIS

DOCTORAL THESIS SUMMARY

UNCONVENTIONAL KINETOTHERAPEUTIC DEVICE FOR MOTOR REHABILITATION AND IMPROVING THE QUALITY OF LIFE

PhD Student,

Murgoci Nicolae

Scientific coordinator,

Prof. habil. Claudiu MEREUȚĂ, PHD

SSEF Series: Science of Sport and Physical Education No.4

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2020 ~ 2023

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Notations and abbreviations

a – y - years
AINS - Nonsteroidal anti-inflammatory drugs
AM - Range of motion
AMA - American Medical Association
ATP - Adenosine triphosphate acid
AVC – stroke
Bpm – beats per minut
B - men
BDNF- brain-derived neurotrophic factor)
BA – Joint Testing
BF - *Biceps femoris* (long head)
C - control
CI - confidence interval
CF - coxo-femoral joint
df - degree of freedom
Dif VAM - average analog value difference
DM – muscle imbalances
E - experiment
F – women
FC - heart rates measured according to the rehabilitation phase
FCR- resting heart rate
FCM - maximum heart rate
FCT- target heart rate
FGF - fibroblast growth factor
FFMI – non-adipose tissue index
FMI - adipose tissue index
G - knee joint
GL - *Gastronemius lateralis*
GM - *Gastrocnemius medialis*
Gmax - *Gluteus maximus*
Gz – the ankle joint
HTAE - essential hypertension
I – effort intensity
iNOS - Inducible nitric oxide synthase
IL – interleukin
IMC – BMI- body mass index
MCS – mental components summarized
MDF- medium density fiberboard
MRC - Medical Research Council
MTF – the metatarsophalangeal joint
mC – the difference of the means of the control group
mE - the difference between the means of the experimental group
N- normative
N(n) - number
NASA- National Aeronautics and Space Administration
Obs - observer
OMS - World Health Organization
QF – interpedal width
QoL – life quality
P (p). - page
PCS – componentele fizice sumarizate
QoL – quality of life
Reflexul H – Hoffmann reflex
RF- *Rectus femoris*
RPE - Evaluation of perceived effort
SPARC - secreted protein acidic and rich in cysteine
SOL - *Soleus*
SM - *Semimembranos;*
SMI - skeletal muscle index
SNC – central nervous system
SNP – peripheral nervous system
SWOT - Strengths, Weaknesses, Opportunities, and Threats
T0 – before the beginning of the physical therapy sessions
T1 – after four weeks of physical therapy
T2 - after eight weeks of physical therapy
TA - *Tibialis anterior*
TCC – craniocerebral trauma
TNF – tumor necrosis factor
V - age
VAS - visual analog pain scale;
VL- *Vastus lateralis*
VM - *Vastus medialis*
VO_2- the volume of oxygen

INTRODUCTION

The pathology of the lower limbs is diverse and with multiple etiologies, being the most frequent cause of pain, incapacity, disability and invalidity, which in the long term have a strong impact on the quality of life. In this context, the increased number of the geriatric population with the baggage of adjacent chronic diseases, as well as the post-COVID-19 effects contribute to increasing the pressure on the social and health system.

Thus, the field of lower limb recovery plays an essential role in order to restore the functional role of the individual, combat the effects of the deconditioning syndrome, social and professional reintegration of patients and improve their quality of life. Early mobilization is currently considered an important aspect of patient care by healthcare professionals, but there is no pre-established routine embodied in a well-established medical rehabilitation protocol.

A treatment plan considers a comprehensive analysis of the patient in order to maximize the results of the applied rehabilitation program.

The rehabilitation of musculoskeletal disorders of the lower limbs takes into account a series of specific principles that must be approached interdependently in order to obtain a favorable response to the treatment.

The paper proposes the analysis of the entire kinetic chain related to the injured joint, biomechanical deficiencies and muscular imbalances that make it difficult to maintain a correct static or dynamic posture in order to apply the functional therapeutic exercises.

The appropriate dosage of therapeutic exercises according to the risk associated with each patient, the basic and associated pathologies, simultaneously with the monitoring of vital functions allows the development of individualized rehabilitation programs according to the individual tolerance.

The advantages of using an improved kinetotherapeutic system involving static horizontal pedaling are multiple. It involves the safety of using the device, facilitates discharge, normalizes cardiac and pulmonary parameters, ensures the maintenance of the viability of myoarthrokinetic structures, shortens recovery time, motivates for independent mobilization, improves cognitive functions and survival rates, prevents disability and sarcopenic state, as well as increases quality of life.

The main objective of physical therapy is the recovery of gait, an objective with multiple valences involving the integrity of the triple flexion/extension chain.

The medical rehabilitation process can be made more efficient by using the horizontal static pedal system, the efficiency indicators used being the statistical interpretations related to the increase in the amplitude of joint movement, the recovery of muscle strength, the reduction of pain, the control of the heart rate, of effort and the reduction of the chronotropic deficit. The individual perception of the quality of life of each patient is a defining element for a successful rehabilitation.
The analysis of the evaluation criteria of the RAND SF-36 V1 quality of life questionnaire was carried out sequentially from the constructive, technical-economic point of view, of the results obtained and its adequacy or appropriateness - the target criterion, which demonstrates whether the content of the questionnaire corresponds to the main purpose of the study, respectively the facilitation of ambulation.

The multiple regression analysis was apllied to compare the efficiency of the rehabilitation programs used, taking into account as independent variables the results obtained according to the battery of tests applied for the evaluation of motor rehabilitation and as dependent variable the results of the stability test.

The constructed horizontal pedaling system proved its statistical efficiency following the correlation of motor rehabilitation results with those of the quality of life questionnaire, a correlation that did not prove statistically significant in the case of the standard physical therapy program, static horizontal pedaling involving methods of synthesis, global activation and synergistic with superior results.

PART I THEORETICAL FOUNDATION OF THE THESIS

CHAPTER 1. INTRODUCTION TO THE SUBJECT OF REHABILITATION MEANS IN THE CURRENT CONTEXT

1.1. The current context of rehabilitation determined by the trend of pathologies and the aging of the population

The increase in the prevalence of degenerative diseases, lifestyle changes and cases of trauma has led to an increase in the number of patients requiring rehabilitation. In addition, the increased number of the geriatric population suffering from chronic diseases contributes significantly to the increase in the need for medical recovery. The emergence of COVID-19 is an unprecedented public health problem that has led to an increased number of hospitalizations. According to the World Health Organization (WHO), a large part of the population will require rehabilitation interventions during and after hospitalization. Patients suffering from COVID-19 are at increased risk of long-term impairment and disability and will require rehabilitation at all stages of the disease (Intelligence, 2021; World Health Organization, 2021).

In Romania, the total number of patients cured of COVID-19 amounted to 3.26 million people at the end of February 2023, representing 97.60% of the total number of infected patients since the beginning of the pandemic. (**Tabel 1.1**)

Tabel 1.1 Total infected/cured of COVID-19 worldwide and in Romania, *processing after (worldometers.info, 2023)*

***Total infected* COVID-19**	**28.02.2023**	**Cured (no.)**	**Cured (%)**
Total persons	679,863,569	652,708,194	96.01%
of which in Romania	**3,340,342**	**3,260,101**	97.60%

According to the studies carried out by the WHO, there are residual symptoms even after 6 months of post-Covid-19 healing, which are more serious in non-hospitalized patients, influencing their quality of life and thus affecting their mobility, good performance of daily activities, leading to impossibility of service resumption.(**Tabel 1.2**)

Tabel 1.2 Post-Covid 19 residual symptoms (after 6 months), *processing after (World Health Organization, 2021,p. 2)*

Post-Covid 19 residual symptoms (after 6 months)	**Hospitalized patients**	**Non-hospitalized patients**
Anxiety, depression (average)	37%	not evaluated
Pain	22%	not evaluated
Reduced exercise tolerance (average)	27%	not evaluated
Functional limitations	50%	not evaluated
Decreased quality of life	53%*	83%
Affecting the mobility and the performance of daily activities	33%	66%
Failure to resume service	29%	17%
Dependent on care	neevaluat	31%

*patients over 60 years of age

Physical therapy for patients with COVID-19 not only reduces mortality, recovery time, and medical expenses, but also saves medical resources, reduces personal and national economic losses, and the likelihood of social instability adverse events such as medical collapse (Zhu et al., 2020).

According to the report on population aging, globally in 2019 there were approximately 703 million people aged over 65, a number that will reach 1.5 billion in 2050. Globally, the share of the population aged over 65 has increased from 6% in 1990 to 9% in 2019 and 10% in 2022. This proportion is expected to increase further to 16% in 2050, when one in six people worldwide over 65 years is expected to require an assistive device for gait support (Intelligence, 2021; Mordor Intelligence LLP, 2021; United Nations Department of Economic and Social Affairs, 2019). – **Figure 1.1.**

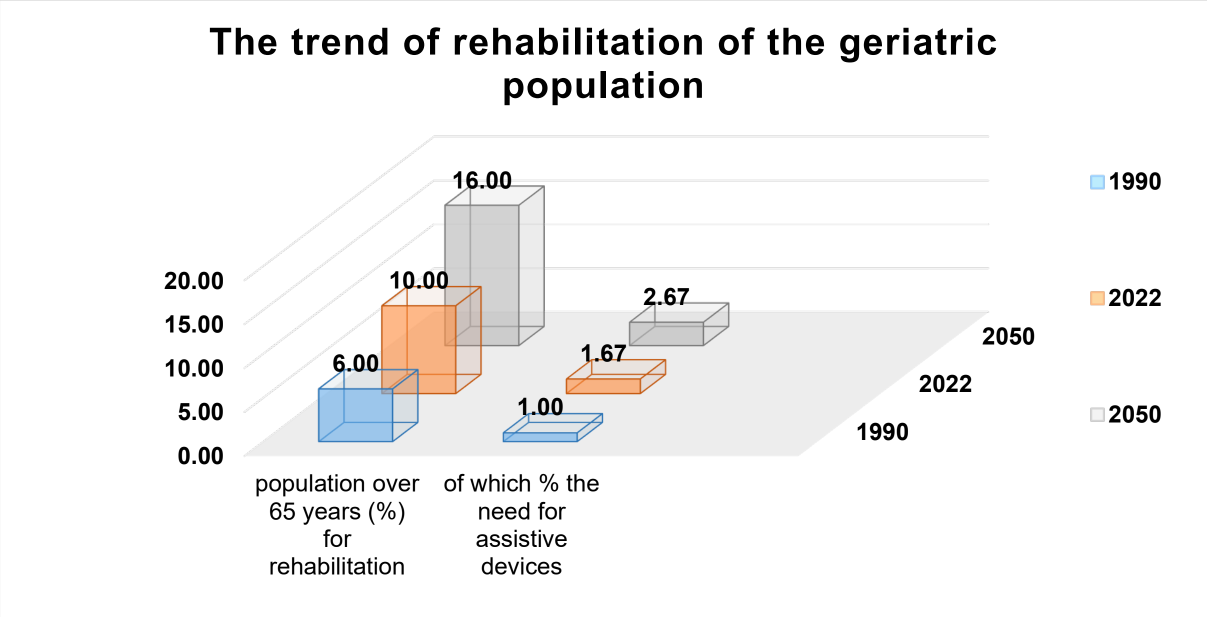


Figure 1.1 The trend of rehabilitation of the geriatric population, *processing after* (Intelligence, 2021; Mordor Intelligence LLP, 2021; United Nations Department of Economic and Social Affairs, 2019)

The deconditioning syndrome of the elderly involves the direct effects of age including a series of neuromotor maladaptations (Tudor Sbenghe, 2002, p. 7, 394-402) defined by the terms **sarcopeni**a and **dynapenia** according to the latest studies (Arakawa et al., 2018; A. Foster, 2019; Seene & Kaasik, 2012; Wroblewski et al., 2011).

The rate of muscle loss varies from 1% to 2% per year after the age of 50, resulting in 25% of people under the age of 70 and 40% of those over the age of 80 being **sarcopenic** (Seene & Kaasik, 2012)**.**

Sarcopenia has been considered to be a minor modifiable risk factor for health outcomes and plays a significant role in the etiology of disability. Sarcopenia is understood as an age-related loss of muscle mass, muscle strength and physical function (Seene & Kaasik, 2012)**.** The term sarcopenia was defined as the age-related loss of muscle mass and the term dynapenia as the age-related loss of muscle strength..

Maladaptations (**Tabel 1.3**) include strength decline, muscle fatigue, reflex responses and rapid motor reactions altered by delayed reaction times, disruption of postural mechanics, and the inability to maintain submaximal force control (Enoka, 2008, p. 394-403; Tudor Sbenghe, 2002, p. 606-609).

Tabel 1.3 Age-related maladaptations, *after (Enoka, 2008, p. 394-403; Tudor Sbenghe, 2002, p. 606-609)*

Age-related maladaptations	Details
Muscle strength	The decline starts from the age of 60 simultaneously with the decrease in muscle mass. Regaining muscle strength is possible following an appropriate medical rehabilitation program, type II muscle fibers can experience muscle hypertrophy with appropriate rehabilitation.
Muscle fatigue	It is not pathognomonic for the 3rd age, the incidence being however higher in men, women being less affected by muscle fatigue.
The responses of osteotendinous reflexes and the ability of rapid motor reaction	With age, neuromotor deconditioning occurs due to the decrease in muscle fiber excitability. In the elderly, the patellar tendon reflex has an increased latency and a low amplitude, with longer reaction times.
Maintaining the posture	Posture is difficult for the elderly to maintain due to abnormal selection of sensory information, poor detection of body imbalance and correct posture, delay in quick reaction responses, insufficient perception related to stability, decreased muscle strength and poor coordination of synergistic muscles.
The ability to control submaximal force	Force control decreases with age and is manifested by the impossibility of performing activities that involve a constant force.

1.2. Therapeutic devices used in rehabilitation

According to Global Market Insights, the rehabilitation equipment market size exceeded USD 18.6 billion in 2019 and is poised to grow at over 7.8% CAGR (Compound annual growth rate) between 2020 and 2026 (31.2 billion USD). The annual compound growth rate is a dynamic commensuration indicator. Increasing interest in research and development to develop innovative products anticipates the growing need for efficient and accurate rehabilitation equipment. Favorable health sector reforms and reimbursement policies in developed countries are major factors that have led to demand expansion (Rupali Swain, 2020).

The main physical therapy devices target, in descending order, musculoskeletal (70.43%), neurological (15.05%) and cardiopulmonary (14.52%) rehabilitation equipment according to the report on rehabilitation equipment prepared by Global Market Insights 2019 (**Figure 1.2**).

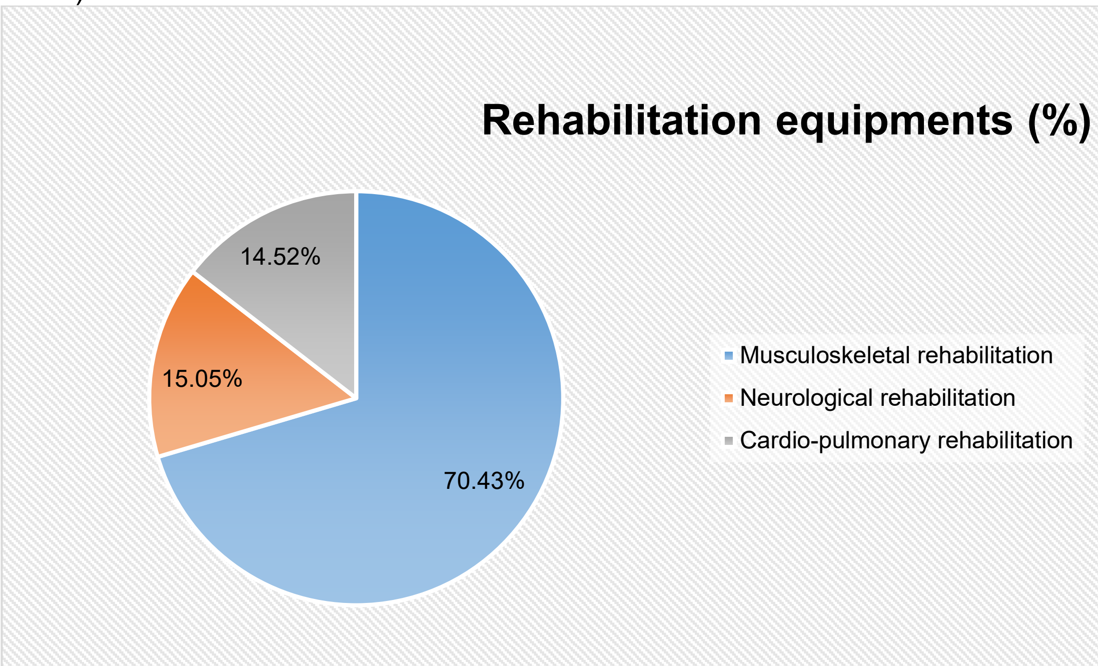


Figure 1.2 Musculoskeletal, neurological and cardiopulmonary rehabilitation equipment, adaptation after (Rupali Swain, 2020)

Musculoskeletal conditions are prevalent and their impact is ubiquitous, being the most common causes of pain and severe long-term physical disability. According to data from the World Health Organization (WHO), 1.71 billion (21%) worldwide are currently living with a painful musculoskeletal condition, their prevalence increasing with age, as well as the associated socio-economic costs (Cieza et al., 2020; Rupali Swain, 2020; World Health Organization, 2022). Access to rehabilitation services is essential, especially as one person in three in the world requires rehabilitation during the course of at least one disease (Institute for Health Metrics and Evaluation, 2020; Rupali Swain, 2020) and musculoskeletal disorders can increase the risk of developing chronic diseases: cardiovascular, obesity, diabetes, neoplasia, chronic lung diseases (Rupali Swain, 2020; Williams et al., 2018; World Health Organization, 2022). Low back pain is the most representative and has multiple implications for the quality of life (Hartvigsen et al., 2018; World Health Organization, 2022).

The neurological rehabilitation equipment market is anticipated to expand at a CAGR of 14.2% by 2026 driven by the increasing incidence of neurological disorders, robotic rehabilitation, and increasing geriatric population suffering from neurocognitive disorders. Patients suffering from neurological disorders such as stroke, cerebral palsy, multiple sclerosis and brain surgery frequently require neurorehabilitation. The advent of the latest technologies has led to the development of advanced medical equipment such as anti-gravity treadmills and robotics to assist patients with ambulation recovery. Robotic anti-gravity treadmills allow patients with neurological conditions to regain or improve their ability to move or walk, while reducing pain and pressure on the osteo-articular system. Advances in robotics and software help therapy professionals provide more accurate diagnoses and enhance their clinical skills (Rupali Swain, 2020).

The cardiopulmonary rehabilitation equipment segment was valued at more than USD 2.5 billion in 2019 due to the growing need for rehabilitation therapy among people suffering from cardiopulmonary disorders. Exercise capacity is limited in patients diagnosed with chronic obstructive pulmonary disease and congestive heart failure. Patients suffering from cardiovascular disorders and hypertension require continuous monitoring (Rupali Swain, 2020).

Therapeutic means are the way to act to achieve a certain goal. They can be seen as a method, a manner, a way to achieve an objective.

The means of therapy are classified into the following three categories, the classification being strictly medical:

- specific means: physical exercise, posture, ergotherapy and massage;
- non-specific means: natural physical agents, artificial physical agents, psychic means, immobilization, diet;
- complex means: hydrothermokinetotherapy.

The specific kinetotherapeutic means are classified into 4 large categories according to the analysis report carried out by GrandViewRecearch în (Grand View Rresearch, 2018):
a) mobility equipments;
b) daily living aids;
c) body support devices;
d) **exercise equipments**. (**Tabel 1.4**)
To these is added rehabilitation robotics, which has benefited from a special interest recently.

Tabel 1.4 Main groups of rehabilitation equipment, *adaptation after (Grand View Rresearch, 2018; Intelligence, 2021)*

Classification of the main groups of equipment			
1. Mobility equipments	**2. Daily living aids**	**3. Body support devices**	**4. Exercise equipments**
1.1 Manual / electric wheelchairs /scooters 1.2 Walking assistance devices: canes, crutches and support frames	2.1 Medical beds 2.2 Assistive devices for toilet and bathroom 2.3 Aids in reading, writing and using computers 2.4 Other daily necessities (feeding aids, positioning products, care and dressing aids and furniture accessories)	3.1 Lifts for patients 3.2 Straps 3.3 Other body support devices (support straps, side transfer plates, sliding sheets, orthopedic aids and accessories)	4.1 Equipment for the lower limbs 4.2 Equipment for the upper limbs 4.3 Full body equipment 4.4 Therapy equipment Exercise equipment used in rehabilitation consists of arm, chest and leg exercisers, different types of bicycles, complex exercise chairs, manual exercise kit, simple/compact shoulder wheels, manual exercise tables.
They are preferred by the target population due to their low price and simplicity	It targets the physically disabled, patients with physical limitations and patients undergoing post-operative rehabilitation		It targets the general population

The rehabilitation equipment market is segmented into i) strength, endurance and pain reduction; ii) physical rehabilitation and training; iii) rehabilitation and vocational training. The physical rehabilitation and training segment is anticipated to witness growth due to the high incidence of sports injuries, degenerative joint disorders and cerebrovascular diseases (Intelligence, 2021).

The fields of application of **kinetotherapeutic devices** (**Figure 1.3**) include two segments: physiotherapy - 22.5%, which contains equipment for physical exercises used in the rehabilitation of patients after trauma or the onset of degenerative diseases, and occupational therapy - 77.5%, which has a holistic approach (Grand View Rresearch, 2018).

Exercise equipment offers patients the possibility of social and professional reintegration, resuming personal activities, improving motivation and relieving health systems of a series of additional expenses.

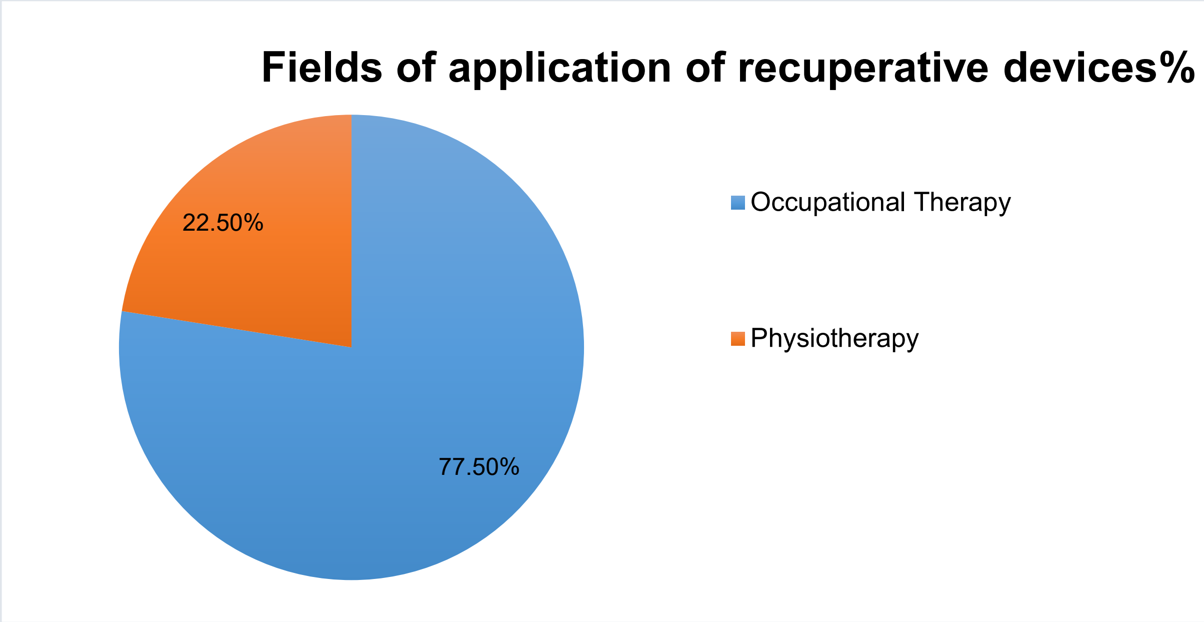


Figure 1.3 Fields of application of recuperative devices, adaptation according to (Grand View Research, 2018)

Changing the predominantly sedentary lifestyle, the growing geriatric population, technological advances (exoskeletons, virtual reality, robots) and pain management through implantable technologies are determining factors for performing physiotherapy.

Physical therapy uses a variety of techniques to restore, maintain, and improve a person's physical strength and mobility after trauma, surgery, and chronic illness.

Occupational therapy facilitates the patient's daily activities based on a comprehensive assessment of the patient, his family and the environment.

CHAPTER 2. THE REFLECTION OF THE THEME IN SPECIALTY LITERATURE AND THE MOTIVATION OF ITS CHOICE

2.2 General considerations regarding exercise bicycles (stationary)

Static or exercise bikes are used for training (to increase resistance), body maintenance (weight loss) and rehabilitation procedures after various injuries of different apparatuses and systems, the difference being the time of application of the program, intensity (resistance), rhythm , number of revolutions per minute and the monitoring parameters used.

The stationary bicycle is indicated in physical therapy due to the fact that it does not require the cardiovascular system, being a device with low impact, safe and effective. Joint stress is maintained at a level considered moderate with the help of exercise bikes, thus facilitating tissue regeneration processes through low-impact movement. Exercise tests are useful for diagnosis, stationary bikes can be used as ergometers to measure pedaling power against a predetermined mechanical resistance level (Vandewalle & Driss, 2015).

Modern ergometers and exercise bikes are equipped with sensors and electronic displays. For example, the cycle ergometer with vibration isolation and stabilization system is used by NASA in space to counteract cardiovascular deconditioning in the microgravity environment (Hackney et al., 2015).

Stationary mini-bikes promote fat burning, improve glycemic levels, joint mobility, contributing to a general toning of the body due to the improvement of general circulation (Stepper-guide.com, 2020). Stationary mini-bikes are often used for the recovery of neuromotor deficits determined by different etiologies (garagegymplanner.com, 2020).

The stationary exercise bikes most often used are the upright ones, but there is the problem of an important category of patients who have not preserved or developed the consolidated balance reaction while sitting in order to initiate the rehabilitation protocol from the orthostatic position.

2.3 Studies attesting the reliability of using the horizontal bicycles in rehabilitation

A number of medical studies listed below (Shibata et al., 2010) have demonstrated the reliability of the horizontal bike in musculoskeletal and cardiovascular recovery in patients hospitalized in intensive care, who were simultaneously receiving supportive treatment for the underlying conditions, in order to counteract the consequences of the immobilization syndrome:

- daily supine pedaling for 2-8 weeks in 21 patients improved heart pumping function and prevented orthostatic hypotension due to prolonged recumbency (Shibata et al., 2010);
- performing exercise concurrently with volume repletion had the same favorable effect, concluding that hypovolemia and cardiac damage are independently responsible for orthostatic intolerance after bed rest (Shibata et al., 2010);
- the study was carried out on the basis of a NASA grant, the results can also be used for motor rehabilitation after space missions where the lack of gravity influences body fluid dynamics and neuro-musculo-skeletal activity (Shibata et al., 2010);
- another randomized controlled trial added to the standard protocol of 68 critically mechanically ventilated patients, sessions of horizontal pedaling that led to the preservation of musculoskeletal architecture, shorter hospitalization and independent mobilization, improved cognitive functions and survival rates (Nickels et al., 2017);
- the feasibility and safety of the horizontal pedaling technique was demonstrated for 181 patients admitted to intensive care (Kho et al., 2015) and for 33 hemodynamically stable patients during the first 4 days of mechanical ventilation (Kho et al., 2016);
- supine pedaling exercise in bed applied to 11 intensive care patients led to their early mobilization, participation that motivated patients to be active in their recuperative act to regain their health after the critical period of hospitalization (Ringdal et al., 2018);
- early mobilization by pedaling has been shown to be a safe technique and has been associated with early weaning from mechanical ventilation (Ringdal et al., 2018);

- it was concluded that the prevention and reduction of muscle weakness can persist up to one year after discharge and of physical deficit even up to 5 years in the case of chronic diseases (Ringdal et al., 2018).

According to the studies presented, the advantages of using an improved kinetotherapeutic system involving horizontal pedaling can be identified:

- the safety of using the device;
- normalization of cardiac parameters;
- maintaining the viability of myo-arthro-kinetic structures;
- shortening the hospitalization time;
- motivation for independent mobilization;
- improvement of cognitive functions and survival rates;
- prevention and reduction of neuromotor deficit.

Although early mobilization is considered an important aspect of patient care by health professionals, there is no predetermined routine materialized over time in terms of intensity and number of sessions. Pedaling did not induce changes or adverse events following monitoring for feasibility and safety.

Pedaling exercise equipment involves the safety of using the device providing patients with independence, psychological, emotional and physical benefits due to the clinical substrate of their testing.

2.4. Conditions that involve pedaling recovery of the lower limbs

Pedaling is recommended as an adjunct in preparing the body for the program itself (warm-up) or it can be included in rehabilitation programs for general mobility, muscle resistance, reduction of edema (Dunleavy & Slowik, 2019, p. 221-222,294), causing a tolerance of movement to the limit of pain (Dunleavy & Slowik, 2019, p. 276), favored by load discharge especially on horizontal bikes. Pedaling with low resistance in order to adapt the body to active effort gradually contributes to the increase of tissue temperature, favoring the extensibility of collagen and implicitly flexibility and joint amplitude (O'Sullivan et al., 2019, p. 384).

The pedaling warm-up component gradually increases the heart rate, ensuring the homeostasis of the cardio-respiratory system by inducing aerobic exercise, being a solution for patients with severe lung diseases (O'Sullivan et al., 2019, p. 451, 511). Gradual exercise therapy involving pedaling is used in patients experiencing deconditioning fatigue syndrome in patients with low exercise tolerance, with target heart rate monitoring (Elizabeth Bryan, 2018, p. 11).

A number of spinal disorders benefit from the recommendation for the use of the bicycle in the recovery protocol such as lumbar spondylolisthesis by promoting spinal flexion (Elizabeth Bryan, 2018, p. 155; physio-pedia.com, 2022), spinal stenosis by progressive pedaling (Elizabeth Bryan, 2018, p.158), scoliosis, through the general conditioning of the cardiovascular function (Elizabeth Bryan, 2018, p. 160).

Post-operatively, pedaling without resistance is indicated for the recovery of injuries (detachment of the origin) of hamstrings, total knee arthroplasty after remission of the painful phenomenon (Elizabeth Bryan, 2018, p.448, 466) and reducing the effects of stiffness after acetabular labrum arthroplasty and capsular reconstruction (Carolyn Kisner, Lynn Allen Colby, 2018, p. 723). To restore the anterior and posterior pinched ligament, it is recommended to pedal with the knee flexed at 90-100 degrees, the contralateral healthy leg facilitating the rhythmic cyclic movement of the affected one (Elizabeth Bryan, 2018, p. 455, 462).

To improve cardio-pulmonary endurance, pedaling using a stationary bike is performed with full knee extension, low resistance and progression to tolerance in order to maintain low impact on the body (Carolyn Kisner, Lynn Allen Colby, 2018, p. 779).

For the rehabilitation of specific conditions of the lower limbs regarding the pathologies of the coxo-femoral joint and the knee (including capsulitis, tendinitis, post-fracture/dislocation/sprain statuses), increasing the strength and resistance of the thigh and knee muscles is obtained by maximally extending the knee during pedaling and increasing the articular amplitudes being subsequently achieved by pedaling with progressive knee flexion (Carolyn Kisner, Lynn Allen Colby, 2018, p. 789).

For neuromuscular control, proprioception, stability and balance, it is recommended to pedal a stationary bike with active knee extension at a minimum of 110 degrees, avoiding joint laxity, the isometric muscle strength of the quadriceps being 50-60% of the contralateral lower limb (Carolyn Kisner, Lynn Allen Colby, 2018, p. 819). The targeted conditions are ischemic or hemorrhagic stroke, multiple sclerosis, central and peripheral motor neuron syndromes, after surgical excision of brain tumors, post cranio-cerebral and vertebro-medullary trauma.

Exercise bikes are therapeutic means for people with nervous system injuries. The treatment plan addresses deficiencies directly or through compensatory strategies, taking into account the patient's background physical condition to maintain aerobic conditioning (Braddom, 2011, p. 1293).

A special application of the therapeutic program are patients with motor function deficits who may develop weak muscle resistance and fatigue (multiple sclerosis, Guillain-Barré syndrome, chronic fatigue syndrome and post-polio syndrome). With the onset of fatigue, through the chronic overdose of therapeutic physical exercises, there is a decrease in strength progressing towards total exhaustion with a ceiling effect. Patients with chronic and irreversible diseases (multiple sclerosis, amyotrophic lateral sclerosis) need targeted intervention (tertiary prevention) to limit the sequelae and degree of disability. The benefits of low-resistance pedaling include maintenance of joint flexibility, tissue extensibility, abilities for daily tasks, and functional mobility. In addition, circulation is improved and pain is inhibited (O'Sullivan et al., 2019, p. 334).

Patients with impaired motor function and balance are unable to respond effectively to external disturbances and stationary cycling achieves reactive balance control (O'Sullivan et al., 2019, p. 388). Pedaling starting from the supine position strengthens the dynamic balance in the sitting position preparing the patient for the next phase of rehabilitation.

Pedaling reduces the risk of re-injury after reconstruction of the lateral ligament of the ankle, improving muscle performance when performed with minimal resistance and using it for at least 30 minutes favors lymphatic drainage of the lower limbs (Carolyn Kisner, Lynn Allen Colby, 2018, p. 828, 879, 1035).

Exercise bikes have clinical relevance for quadriceps, hamstrings, glutes from the range of 35-50 rotations per minute (Braddom, 2011, p. 511). Stationary cycling is recommended for the rehabilitation of post-traumatic osteoarthritis characterized by a chronically unstable knee (Braddom, 2011, p. 911), eccentric strength training by pedaling is also effective in the rehabilitation of chronic Achilles tendinopathy because the ankle plantar flexors work synergistically with the knee and hip extensors (Braddom, 2011, p. 917).

At the end of a therapeutic program, pedaling has a cooling effect (cool-down), preventing muscle spasms and post-exercise pain (O'Sullivan et al., 2019, p. 384), especially after resistance exercises (Carolyn Kisner, Lynn Allen Colby, 2018, p. 202). The 5 to 10 minute cooling phase is used to promote venous return and avoid adverse effects such as post-exercise hypotension, angina, ST-T ischemic changes, and ventricular arrhythmias (O'Sullivan et al., 2019, p. 511).

Patients diagnosed with articular rheumatism or osteoarthritis are usually deconditioned compared to the general population. Cycling reported significant improvements in aerobic capacity and activity levels through regular cardiovascular conditioning without joint damage and other disease symptoms. Own weight is a barrier in performing physical exercises and stationary pedaling favors unloading, constituting a safe and effective means, being an aerobic exercise, an increase in self-esteem and an improved emotional state are reported (O'Sullivan et al., 2019, p. 1030) in patients with chronic rheumatic diseases (not in the acute phase).

Patients with burns show a decrease in physical functionality related to hypermetabolism, prolonged bed rest, low aerobic capacity, underweight status, elements that qualify them for pedaling due to the reduced impact. The rehabilitation program also includes monitoring of pulse, blood pressure and respiratory rate before, during rehabilitation and after exercise, especially during the post-exercise recovery period. Horizontal pedaling increases cardiovascular endurance, but may also have the benefit of improving limb strength and range of motion (O'Sullivan et al., 2019, p. 1030-1031).

Stationary cycling due to the low impact can be used as a recovery treatment in metabolic diseases, osteoporosis/osteopenia/osteomalacia and Paget's disease of the bone.

Pedaling contributes to functional strengthening, training posture and body mechanics and correcting kinetic chain deficiencies (Braddom, 2011, p. 879, 922).

2.5. The motivation for choosing the theme

The predilection for the bicycle from the range of exercise devices is based on the fact that it is directly involved in the active musculo-skeletal, cardio-pulmonary and neuro-motor recovery of the patient, compared to the other kinetotherapeutic means that have an indirect, passive role, with specifying that all types of kinetotherapeutic means contribute to improving the quality of life.

I mention that I have an experience of over 11 years in the field of physiotherapy at home. I graduated, within the "Dunării de Jos" Galati University, the Faculty of Physical Education and Sport, specializing in Physiotherapy and special motor skills in 2011. The master's degree programs completed were Physiotherapy at home completed in 2013, followed by Nutrition, completed in 2019 within the Faculty of Food Science and Engineering.

Since 2011, I have been practicing the profession of physiotherapist and since 2016 in accordance with the medical credentials related to the free practice office for public activities related to the medical act within Murgoci I. Nicolae - Individual Practice Cabinet - Physiotherapy, registered in the Single Register of Medical Cabinets- part 3 of the Directorate of Public Health of Galati County under no. 096732 / 149 of 11.03.2016.

The choice to develop a horizontal pedal board adapted to the needs of patients resulted from personal observations related to the own portfolio from 2017-2019 regarding the increasing number of patients discharged at home, in the therapeutic window of intervention, demotivated for which bringing them into an orthostatic position required minimal a month of motor rehabilitation. The pathologies that prevailed were lower limb traumas, generally surgically reduced fractures with osteo-synthesis, patients with prostheses at the coxo-femoral and knee joints, post-ischemic stroke patients – bedridden patients whose gait rehabilitation was later quite difficult.

There are available various medical bicycles and/or pedals used for kinetotherapeutic purposes and for the recovery of various ailments, traded by sales companies but not approved by specialists in the field of recuperative kinesiotherapy who require from the patient uncomfortable positions not adapted to the rehabilitation process or which require improvisations.

There is practically no horizontal bicycle approved for recovery on the market even at the moment. Losing the start of the rehabilitation act has socio-economic implications, the patient becoming demotivated and non-compliant with the therapeutic exercises prescribed by the rehabilitation doctor and physiotherapist. Thus, patients' recovery is compromised due to the lack of a tool to improve their health starting from the supine position (in bed). For this purpose, the horizontal bicycle is an active element of the act of rehabilitation through physical therapy, favoring the recovery process and regaining independence, unlike the classic approach that emphasizes the initiation of passive physical therapy in the first phase.

The proposed static horizontal pedaling device adapted to the horizontal position of the human body is based on a new approach that will include anthropometric measurements of the human body and the adjacent risk, followed by the establishment of an individualized pedaling program that will be included in a rehabilitation protocol adapted to the pathology of each patient. With the help of the innovative horizontal pedal board, I propose to demonstrate the effectiveness of its application for the recovery of patients temporarily immobilized in bed who require physical therapy at home. Each stage of the work is supported by prospective cohort analytical scientific studies to verify the working hypotheses and compare the classical approach methods with the proposed ones. Predominantly qualitative research is based on the evaluation of pain intensity, joint and muscle balance, the highlighting of muscle imbalances with monitoring of heart rate and perceived effort, respectively the comparative study regarding the improvement of the quality of life. To these are added the perspectives identified, based on the research carried out.

In this context, I express my firm conviction that the innovative static horizontal pedal board will bring a significant contribution to patients and added value to the field of medical rehabilita

CHAPTER 4. REHABILITATION OF THE LOWER LIMBS

4.1. The role of kinesiology in motor rehabilitation

4.1.1. The relationship between kinesiology - pathokinesiology - kinesiopathology - medical kinetology

Kinesiology, according to the term introduced by Dally in 1857 in Paris, was defined as the science of movement.

Kinesiology can be viewed as a science, profession or discipline.

The scientific aspect of kinesiology includes biomechanics (the application of the laws of mechanics to the study of movement = mechanical kinesiology), applied anatomy - the relationship between structure and function and the physical analysis of movement as well as exercise physiology and psychomotor behavior (Renson, 2000; Sporis et al., 2013; Tudor Sbenghe, 2002, p. 18-24).

The definition of medical kinesiology as opposed to the non-medical one (which studies human motility unrelated to pathology and treatment) is the study of the neuro-myo-arthro-kinetic components that ensure the development of normal motility by recording, analyzing and correcting deficient mechanisms using physical therapy (Tudor Sbenghe, 2002, p. 18-24).

The pathokinesiological model (**Figure 4.1**) describes the role of a disease or injury that produces changes in movement components, disability or deficiencies causing functional limitations with the possible end result of establishing a disabling *status* (Shirley Sahrmann, 2002, p. 10-16).

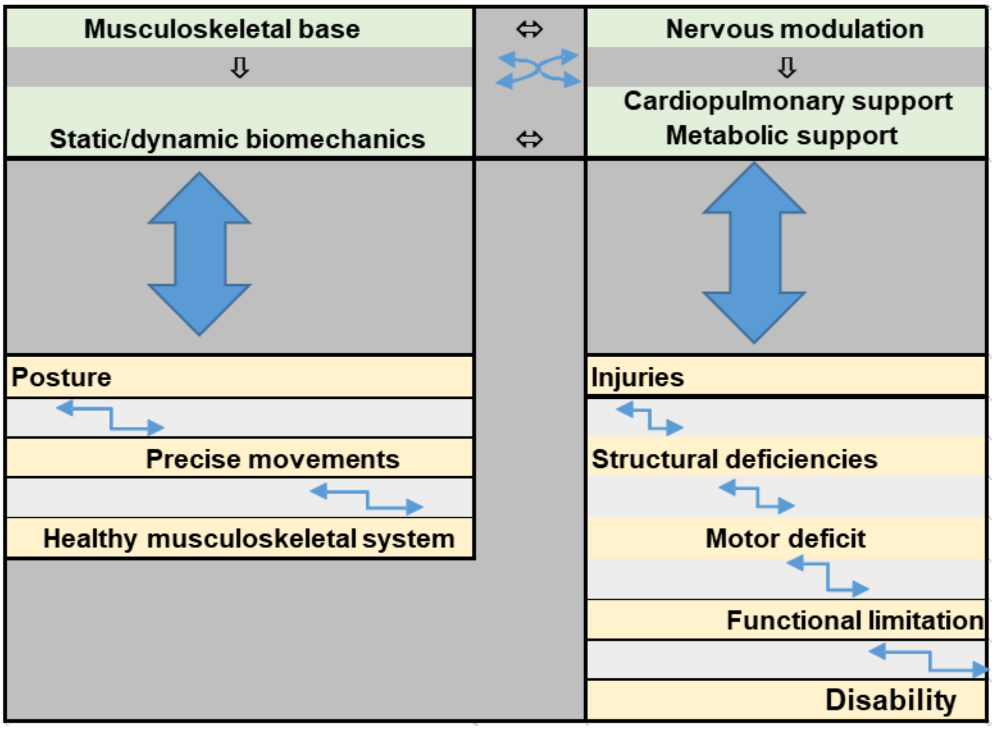


Figure 4.1 The pathokinesiological model, adaptation after (Shirley Sahrmann, 2002, p. 10-16)

The kinesiopathological model (**Figure 4.2**) involves movement abnormalities performed in daily activities that can cause disturbances that ultimately lead to the appearance of a pathology. It characterizes the role of movement in the production of deficiencies. The empirical basis of this model comes from the observation that repetitive movements and sustained postures affect musculoskeletal structures and neural tissue. The cumulative effect of repetitive movements is tissue damage, especially in movements that deviate from the kinesiological standard (Shirley Sahrmann, 2002, p. 10-16).

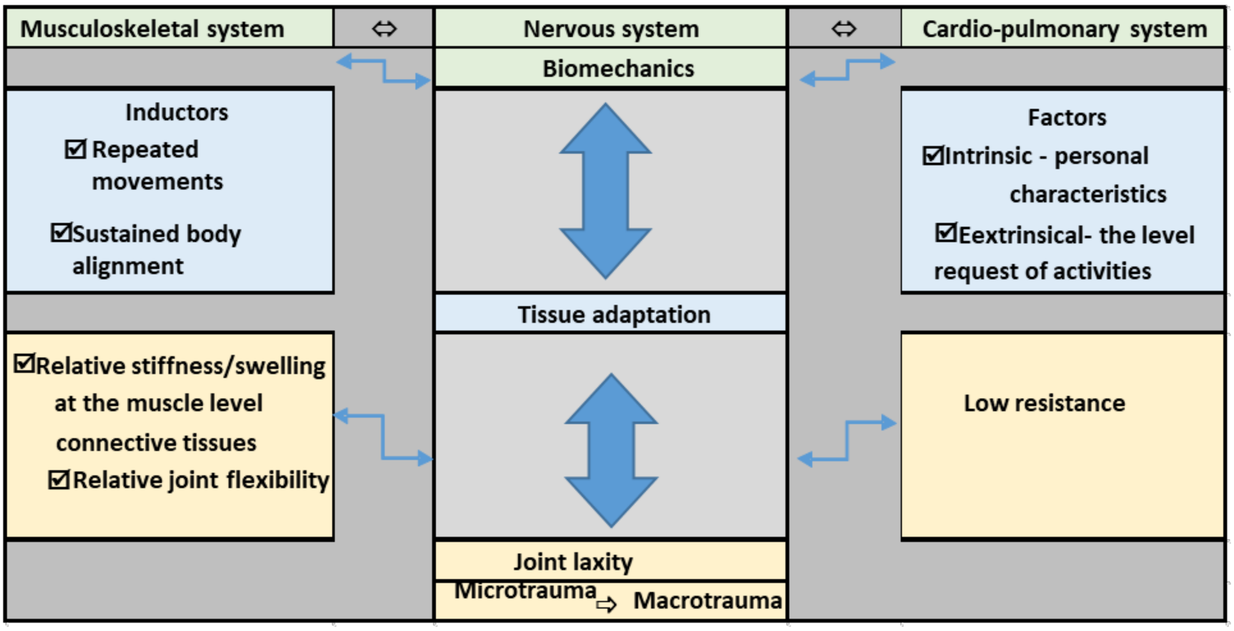


Figure 4.2 The kinesiopathological model, adaptation after (Shirley Sahrmann, 2002, p. 10-16)

Medical rehabilitation aims both at correcting deficiencies resulting from an injury and as a result of faulty movement patterns resulting from the performance of daily activities.

4.2. Principles of lower limb rehabilitation and the phases of rehabilitation and therapy with physical exercise

4.2.1. The principles of rehabilitation of musculoskeletal disorders of the lower limbs

The rehabilitation of musculoskeletal disorders of the lower limbs takes into account a series of specific principles that must be approached interdependently in order to obtain a favorable response to treatment based on the basic medical rule *primum non-nocere.*

The movement models analyze the entire kinetic chain related to the injured joint, the biomechanical deficiencies and muscle imbalances that make it difficult to maintain a correct static or dynamic posture in order to properly apply functional therapeutic exercises, dosed according to the basic and associated pathologies of the patients with the monitoring of vital functions – **Tabel4.2.**

Tabel 4.2 Principles of rehabilitation of the lower limbs, adaptation after (Braddom, 2011, p. 436, 899)

No.	Specification	Details
1	**The principle of the kinetic chain**	→ It analyzes the dysfunction at the level of anatomical regions connected with the painful site, which are linked during movement → A treatment plan restores proper motor function along the entire chain → Kinetic chain analysis is of maximum relevance when discussing muscle and tendon, bone and joint pathological conditions
2	**The principle of biomechanical deficit**	→ Refers to any impairment determined by a reduction in range of motion, flexibility, strength, endurance or motor control
3	**The principle of muscular imbalance**	→Loss of stabilizing capacity from agonists or antagonists, most often at the level of the pelvis anterior-posterior: flexors/extensors of the hip joint, medial-lateral: adductors/abductors of the hip joint
4	**The principle of functional exercise**	→ It is based on the isolation of some muscle groups that work together with other muscle groups in a kinetic chain
5	**The principle of specificity - periodization**	→ Metabolic responses occur depending on the muscle groups involved → The type of adaptation reflects the type and intensity of the therapeutic exercises and the periodization implies the appropriate use of the break

		→ The global rehabilitation program is a macrocycle divided into phases called microcycles, each with specific objectives
6	**The principle of the rehabilitation protocol base**	→ Blood pressure monitoring reveals inotropic performance – the heart's pumping capacity → The critical intensity of therapeutic exercise reaches 47%-64% of the maximum volume of oxygen in untrained healthy people and 70%-90% of the maximum volume of oxygen in healthy trained people - representing the anaerobic threshold (ventilator) → Monitoring of heart rate and perceived exertion is considered to prevent adverse effects.

A treatment plan considers a comprehensive analysis of the patient in order to maximize the results of the applied recovery program.

4.2.6. The anti-inflammatory effect of therapeutic exercise

The inflammatory process is an important aspect of chronic diseases of various etiologies and the pain caused by it can delay the rehabilitation phases of the lower limbs, having a negative impact on the quality of life. Cardiovascular diseases, diabetes, rheumatic diseases in the initial stage are diseases associated with chronic systemic inflammation with low risk. Exercising regularly provides protection against the effects of chronic systemic inflammation. Regular physical activity has multiple health benefits, including weight control, improving heart function, bone density, restoring muscle strength, and reducing the risk of certain diseases. The effect of long-term exercise triggers an anti-inflammatory response, which is partially mediated by muscle-derived IL-6, protecting against TNF-induced insulin resistance. Myokines act as mediators through IL-6, which stimulates the circulation of the anti-inflammatory cytokines IL-1ra and IL-10 and inhibits the production of the pro-inflammatory cytokine TNF-α, favoring lipolysis and fat oxidation (Lee & Jun, 2019; Murgoci, 2022b; Pedersen et al., 2003; Petersen & Pedersen, 2005).

The specific functions of the myokines released by muscle contraction are according to **Table 4.9**, from which we note the decrease in inflammation determined by IL-6 and the increase in fatty acid oxidation, the increase in mitochondrial biogenesis by myonectin and FGF, muscle regeneration/repair determined by SPARC protein, BDNF and the increase in myogenesis by means of decorin (Lee & Jun, 2019; Murgoci, 2022b).

Tabel 4.9 Muscle myokines induced by physical exercise, after (Lee & Jun, 2019; Murgoci, 2022b)

Muscle myokines induced by physical exercise	**Function**
IL-6	**Inflammation ↓,** ↑ Oxidation of fatty acids
Irisine	↑ Oxidation of fatty acids
Myonectin	Autophagy ↓, ↑ **Mitochondrial biogenesis**
Decorin	↑ **Myogenesis**
FGF (21 fibroblast growth factor)	↑ **Mitochondrial biogenesis**
SPARC (secreted protein acidic and rich in cysteine)	↑ **Muscle repair**
IL-15	↑ Fat metabolism, ↑ Myoblast differentiation
BDNF (brain-derived neurotrophic factor)	↑ **Muscle regeneration**, ↑ Oxidation of fatty acids

Persistent systemic inflammation, a typical feature of inflammatory rheumatic diseases, is associated with high cardiovascular risk and predisposes to metabolic disturbances and muscle wasting. These disorders can lead to disability. The decrease in physical activity and the exacerbation of inflammation thus establish a vicious circle of chronic inflammation. Exercițiile fizice sunt folosite ca terapie pentru bolile reumatice. Skeletal muscle communicates with other organs by secreting proteins called myokines. Certain myokines induce anti-inflammatory responses with each training session and mediate long-term improvements in cardiovascular risk factors.

Therefore, exercise is considered to be a potential treatment for patients with rheumatic diseases. Thus, physical exercises act both directly, after each therapy session, and indirectly, by improving cardiovascular risk factors (Benatti & Pedersen, 2014; Murgoci, 2022b).

Therapeutic exercises performed at home to tone the quadriceps muscles improve the status of the analyzed disease, namely osteoarthritis of the knee, in a similar way as NSAID medication (Doi et al., 2008; Murgoci, 2022b). Other reported effects were reduced pain and improved functionality for people with osteoarthritis of the knee (Fransen et al., 2002; Murgoci, 2022b).

Chronic kidney disease is associated with a complex state of immune dysfunction characterized by susceptibility to infections and an increased risk of cardiovascular disease. Exercise can improve immune function and have anti-inflammatory effects. Six months of regular walking exercises (30 min/day 5 times/week) demonstrated anti-inflammatory effects (reduced ratio of IL-6 and IL-10 plasma levels) and a decrease in T-lymphocyte and monocyte activation. Physical exercises did not influence kidney function, proteinuria and blood pressure in chronic kidney disease. Therefore, walking exercise is safe for immune and inflammatory responses and has the potential to be an effective anti-inflammatory therapy in predialysis (Murgoci, 2022b; Viana et al., 2014).

The rehabilitation program significantly reduced the local expression of TNF-alpha, IL-1-beta, IL-6 and iNOS in the skeletal muscle of patients with chronic myocardial infarction. These local anti-inflammatory effects of exercise may attenuate the catabolic wasting process associated with the progression of congestive heart failure (Gielen et al., 2003; Murgoci, 2022b). Exercise in patients with myositis is considered safe, benefits clinical outcome, and may reduce inflammation (Murgoci, 2022b; Nader & Lundberg, 2009).

A moderate exercise session has a cellular response that can help suppress inflammation in the body. A single 20-minute session of moderate-intensity exercise can also act as an anti-inflammatory for chronic diseases such as arthritis, fibromyalgia, obesity and autoimmune diseases. It can also boost the immune system, producing an anti-inflammatory cellular response by reducing the number of stimulated immune cells that produce TNF by five percent. Tumor necrosis factor-TNF is a key regulator of local and systemic inflammation that helps stimulate immune responses. The anti-inflammatory effects of regular exercise may be mediated both by reducing visceral fat mass (with a subsequent decreased release of adipokines) and by inducing an anti-inflammatory environment at each therapy session (Dimitrov et al., 2017; Murgoci, 2022b).

Therefore, pedaling for at least 20 minutes has an anti-inflammatory effect directly correlated with the decrease in pain intensity and indirectly presents the advantages of increasing cardio-pulmonary resistance, maintaining muscle tone, metabolic control and body weight.

CHAPTER 5. CONCLUSIONS PART I

1. The global demand for physical therapy equipment is estimated to grow by 7.8%/year until 2026, of which musculoskeletal rehabilitation equipment represents 70.43%. The cause is the high prevalence of degenerative diseases, traumas and the number of the geriatric population (estimated at 16% in 2050, of which 2.67% will require an assistive device), who suffer from chronic diseases to which are added the effects of the deconditioning syndrome.

2. Romania supports an increasingly aging population, the need for rehabilitation services being moderately upward according to the extended SWOT analysis of kinetotherapeutic means carried out in accordance with the local educational, medical and social assistance legislative measures.

3. Pedaling exercise equipment is a rehabilitation favorite offering patients safety, independence, psychological, emotional and physical benefits and is the focus of ongoing research.

4. The main objective of physical therapy is the gait rehabilitation, an objective with motivational and economic-social implications that facilitates the resumption of personal activities, regaining independence, mobility and increasing the quality of life.

5. A treatment plan considers a comprehensive analysis of the patient in order to maximize the results of the applied recovery program. Rehabilitation comprises three main phases, which address the acute inflammatory post-injury stage (phase I), the early tissue regeneration stage (phase II) and the tissue remodeling stage (phase III).

6. Medical rehabilitation aims both at correcting deficiencies resulting from an injury and as a result of faulty movement patterns resulting from the performance of daily activities.

7. Pedaling activates the three key joints involved in ambulation, favoring dorsiflexion and plantar flexion of the ankle through total extension of the hip, knee/hip flexion being established according to individual tolerance and pathology by changing the distance to the pedals. A simplified model of muscle coordination during pedaling consists of the synergy of the four functional muscle groups. The reflexes involved in the medical recovery of the lower limbs using kinetotherapeutic means are the H (Hoffmann) reflex and the tonic vibratory reflex. Medical applications in recovery for the H reflex are increasing muscle strength in healthy and sick people (amyotrophic lateral sclerosis, multiple sclerosis), facilitating ambulation, and the vibratory tonic reflex is used to recover hemiplegics and reduce spasticity. Masseter contraction during submaximal pedaling can improve lower limb muscle strength.

8. Pedaling for at least 20 minutes has an anti-inflammatory effect directly correlated with the decrease in pain intensity and indirectly presents the advantages of increasing cardio-pulmonary resistance, maintaining muscle tone, metabolic control and body weight.

9. A pedaling system built with fixing the legs through two support bands, one at the level of the calcaneus and the other on the dorsal side of the legs, the load being represented by the own weight of the lower limbs, with resistance in the pedal can be considered on the border between a system controlled by open and closed kinetic chain. It involves the use of three large joints in a rotating sagittal plane, with reinforced balance reaction in long sitting.

10. In this context, I express my firm conviction that the innovative static horizontal pedal board will bring a significant contribution to patients and added value to the field of medical rehabilitation.

PART II PRELIMINARY EXPERIMENTAL RESEARCH ON THE EFFICIENCY OF USING THE HORIZONTAL PEDAL DEVICE IN MOTOR REHABILITATION

CHAPTER 6. GENERAL METHODOLOGICAL FRAMEWORK OF THE PRELIMINARY EXPERIMENTAL RESEARCH

6.1. Premises of preliminary experimental research

The premises considered as a starting point in conducting the experimental study are as follows:

- Specific individualized programs that use horizontal pedals intended for motor rehabilitation for recoverable patients in the critical intervention therapeutic window, i.e. immediately after discharge at home, have not been highlighted in the national and international specialized literature. The target population for the intervention is represented by patients post-prosthesis at the level of the hip or knee joint, post-trauma (falls, work/road/sports accidents, assaults), post-stroke, post-COVID-19 or post-reconstructive surgical interventions at the level tendons and ligaments of the lower limbs, chronic rheumatic diseases;
- The evaluation of the kinetic chain of the triple flexion/extension in the present study is carried out by classical kinetotherapeutic techniques (joint, muscle balance) combined with the results transmitted by the system of sensors attached to the pedals, an aspect that leads to the development of therapeutic decisions to remedy motor deficiencies, correcting muscle imbalances and avoiding compensatory movements to preserve postural alignment;
- The corrective interventions applied in real time are monitored and made aware by the participants in order to engram a correct body movement scheme;
- In the current context of recovery, the need for rehabilitation has increased, being determined by the increase in the prevalence of degenerative diseases, changes in the currently sedentary lifestyle, traumas and the increased number of the geriatric population suffering from chronic diseases that will require assistive devices for support walking in the case of neglecting existing pathologies;
- Physiotherapy for post-COVID-19 patients reduces the mortality rate, recovery time and medical expenses, preventing medical collapse;
- The deconditioning syndrome of the elderly involves the direct effects of age including a series of neuromotor maladaptations, sarcopenia (age-related loss of muscle mass) and dynapenia (age-related loss of muscle strength);
- The use of the static horizontal pedal provides additional motivation to patients who switch from the standard passive or passive-active rehabilitation protocol to the active controlled one;
- Increasing the quality of life of patients and decreasing the socio-economic burden of the medical system;
- The integrity of the kinetic chain of the lower limbs is essential for facilitating ambulation.

6.2. Objectives of preliminary experimental research

In the preliminary experimental research, the following objectives were established:

- Designing, building and testing on a batch of patients the stationary horizontal pedal system, establishing the principles of operation and recording data according to the sensors attached to the pedals and interpreting the data;
- The development of original medical rehabilitation programs with the help of the stationary horizontal pedal system, taking into account the risk profile of the patients;
- Implementation of the protocol, integration of the results in order to determine the efficiency of the functional and structural rehabilitation of the lower limbs;
- Comparing the data obtained with those resulting from the application of a standard physical therapy program by selecting approximately similar intervention samples in terms of age and associated pathologies.

6.3. The purpose of preliminary experimental research

The purpose of the preliminary research is to verify the effectiveness of the proposed recovery programs, applied with the help of the stationary horizontal pedalboard designed and built for the rehabilitation of the lower limbs. The establishment of the efficiency of the use of the horizontal static pedal device integrated in a proposed physical therapy program compared to the standard physical therapy program has been achieved through the statistical interpretation of the obtained data.

6.4 Tasks of preliminary experimental research

The tasks of preliminary experimental research established in accordance with the objectives proposed at this level are as follows:

- Extracting data from the national and international specialized literature regarding the kinetotherapeutic means used in motor rehabilitation, in order to develop the kinetotherapy programs in accordance with the medical prescriptions related to each patient;
- Scientific documentation regarding the design and construction of an unconventional therapeutic means - stationary horizontal pedal board, as well as the methods of recording individual parameters with the help of sensors applied to the pedals;
- Selection from the study of national and international specialized literature of conclusive data to support the implementation of a sustainable program of therapeutic pedaling for rehabilitation;
- Establishing the strategy for conducting the preliminary investigation and, drawing up the organization plan for the preliminary investigation;
- Formulation of research premises and hypotheses;
- Selection of the subjects who participate in the preliminary research in accordance with their informed consent and the norms of professional ethics;
- Establishing the inclusion criteria, the exclusion criteria and the framework of specific evaluation means and processes;
- Establishing the preliminary research methods;
- Initial evaluation of the subjects included in the research, using modern technologies - parameters transmitted by sensors with a diagnostic and therapeutic feedback role, determination of body composition, heart rate and classic instruments - anamnestic data, visual analog scale, joint testing, muscle testing, before implementing the medical rehabilitation protocol using a static horizontal pedal board;
- Conception of medical recovery protocols and their application;
- Elaboration of rehabilitation programs using the stationary horizontal pedal board, adapting the structure of the exercise program by degree of difficulty depending on the patient's risk profile and their comorbidities;
- The final evaluation of the subjects at the end of the preliminary research;
- Data centralization;
- Analysis, processing and statistical-mathematical, graphic and medical interpretation of the results;
- Highlighting the conclusions of the preliminary experimental research;
- Formulation of recommendations and proposals following the application of preliminary experimental research.

6.5. The hypothesis of preliminary experimental research

The preliminary research, based on the premises listed above, aims to verify the following working hypotheses:

Hypothesis 1 – The functional evaluation involving classical methods (anamnesis, joint and muscle testing and pain assessment), computerized (body composition, parameters related to the sensors attached to the pedals expressed in analogue values) and hybrid (reserve heart rate, assessment of perceived effort) has a role both diagnostic (to determine muscle imbalances) as well as therapeutic, corrective as a result of the feedback transmitted.

Hypothesis 2 – Therapeutic pedaling structured according to the patient's riskogram applied in the critical intervention therapeutic window is effective according to the statistical interpretations performed in the experimental group compared to the control group.

The preliminary experimental research was carried out at the patients' homes in accordance with the medical credentials of the free practice cabinet for public activities related to the medical act - Murgoci I. Nicolae - Individual Practice Cabinet - Physiotherapy, registered in the Unique Register of Medical Cabinets - part 3 by the Directorate of Public Health of Galati County under no. 096732 / 149 of 11.03.2016 (**Annex no. 7**), according to internal decision no. 32/20.10.2021, valid for all works and studies carried out for the preparation of the doctoral thesis.

In the experimental preliminary research, a number of ten subjects were included who signed the informed consent form (**Annex no. 1**), through which they expressed their agreement regarding the conditions of participation in this scientific endeavor. The subjects were selected based on inclusion and exclusion criteria.

Inclusion criteria: subjects requiring lower limb rehabilitation - post-prosthetic, post-trauma, post-stroke, post-COVID-19 patients, surgical interventions for the reconstruction of tendons and ligaments related to knee and ankle joints.

Exclusion criteria: any acute, infectious disease, cardio-vascular diseases, decompensated kidneys, any life-threatening situation (acute pulmonary edema, pulmonary embolism, aortic dissection, craniocerebral trauma, acute myocardial infarction), lower limb amputation.

6.6. Stages of preliminary experimental research

The preliminary experimental research was preceded by bibliographic documentation (October 2020-September 2021) regarding the current state of research completed in September 2021 and scientific report no. 1 on the construction and design of unconventional kinetotherapeutic means (October 2021 – March 2022) for motor rehabilitation and improvement quality of life, completed in March 2022.

The stages of the preliminary experimental research proceeded as follows:

- The beginning of the experimental research - elaboration of premises, objectives, research hypotheses - the first half of April 2022;
- The initial evaluation, the period of the second half of April - June 2022, includes the assessment of pain with the visual analogue scale, the establishment of the patient's riskogram by bioimpedance, the joint balance established by goniometry, the muscle balance expressed in MRC units and the assessment of muscle imbalances expressed in the difference of average analog value between lower limbs, determination of cardiac reserve, assessment of perceived effort with the Borg scale;
- The final evaluation, between July and September 2022, includes the assessment of pain with the visual analogue scale, the establishment of the patient's riskogram by bioimpedance, the joint balance established by goniometry, the muscle balance expressed in MRC units and the assessment of muscle imbalances expressed in the difference in the average analogue value between the lower limbs, determining the cardiac reserve, assessing the perceived effort with the Borg scale, collecting the results following the application of the standard and proposed recovery programs for four weeks for each patient;
- Data centralization and processing: October 2022
- Drafting, issuing conclusions November 2022;
- Presentation of scientific report no. 2 (preliminary experimental research): December 2022.

6.7. Scientific research methods

The scientific research methodology recommends, in the elaboration of such a work, a series of specific research methods, of which the following were used:

- Method of bibliographic study;
- The scientific experiment method;
- The method of measuring and evaluating anthropometric indicators, heart rate;
- The method of measurements for the assessment of muscle and joint balance;
- The survey method - the pain evaluation questionnaire - the visual analogue scale and pain perception - the BORG scale;

- The observation method - used throughout the study in order to improve organizational dysfunctions;
- The method of biomechanics analysis with the help of computer technology with the help of the sensors of the horizontal pedal system;
- Graphical and tabular method - for the suggestive illustration of the relationship between two or more quantities;
- The graphic method was used to highlight the differences more easily and to interpret the evolution of the studied phenomenon;
- The statistical-mathematical and graphic method of data processing, in order to express the qualitative and quantitative results using SPSS version 25 and Microsoft Excel;
- The logical method thus facilitating the identification of correlations intended to discover elements of progress.

6.8 Evaluation of the subjects

The evaluation of the subjects took into account the following examinations before, during and after the application of the standard and proposed physical therapy programs involving the static horizontal pedal board:

- Patient anamnesis in order to be included in the inclusion or exclusion criteria in the study, as the case may be;
- Information about the experimental study, obtaining consent for the application of the standard and proposed physical therapy programs involving the static horizontal pedal board;
- Functional clinical examination: inspection, palpation, functional tests depending on the pathology;
- Determining the body composition to determine the risk diagram of the patients and apply the appropriate pedaling program;
- Application of the visual analogue pain scale (VAS);
- Joint balance - assessment of the range of motion in the ankle, knee and hip joints by goniometry;
- Muscle balance - evaluation in MRC units;
- Muscular imbalances – evaluation with the static horizontal pedal system expressed in average analog values for the right and left lower limb and the highlighting of the differences between them;
- Target heart rate – assessment applying the Karvonen formula;
- Borg perpetual effort scale to maintain adherence to the treatment and not exceed the lactate threshold during the application of the physical therapy sessions.

6.8.1. Anamnestic data

The patient's history includes information related to age, gender, personal and pathological history, living and working conditions, comorbidities, personal medication, allergies, pain description (mechanical, inflammatory, mixed, neurogenic, neuropathic, acute, subacute, chronic) in order to the inclusion or exclusion criteria in the study, as the case may be.

Functional clinical examination included inspection, palpation, functional tests according to pathology to exclude the acute stage of medical intervention with addressability in emergency medicine units.

6.8.2. Body composition

Body composition identifies the amount of adipose tissue, non-fat tissue and skeletal muscle mass based on each patient's input data (age, weight, height).

The risk diagram of each patient was established based on the bioimpedance parameters for determining body composition, namely values expressed in kilograms for skeletal muscles (SM), adipose tissue (FM) and non-adipose tissue (FFM), respectively their calculated indices by adjusting with the square of each patient's height (FMI = FM/height2, FFMI =FFM/height2). The reference values used the revised European consensus on the definition and diagnosis of sarcopenia (Cruz-Jentoft et al., 2019) and the determination of the somatotype related to adipose tissue, respectively non-adipose tissue in correspondence with its adjustment with the square of the height of each patient (Hattori et al., 1997).

Body composition measurements obtained by bioimpedance used the Amazfit Smart Scale - Body Composition Analyzer (Declaration of Conformity with directives 2014/53/EU and 2014/65/EU) from the free practice cabinet's own endowment, using a single frequency of 50 kHz. For each subject, the major body compartments were determined, automatically estimated by linear empirical equations stored in the system memory along with personal physical data (age, weight, height).

• The exclusion criteria related to bioimpedance measurements included all situations of alteration of the hydroelectrolytic balance (hepatic, renal, decompensated heart diseases), acute-contagious infections, subjects wearing pacemakers, people with skin lesions and pregnant women.

• Inclusion criteria related to bioimpedance measurements targeted any patient with a medical indication for physical therapy from the specialist doctor; restrict the consumption of food and liquids for at least 4 hours and alcohol for at least 8 hours before the test.

• Procedure: subjects in orthostatism with bare feet in contact with the conductive surface.

6.8.3. Visual analog scale

The visual analog scale VAS = [0-10] evaluates the intensity of the pain that the patient complains about. The VAS is a unidimensional measure of pain intensity, used to record the progression of patients' pain or to compare the change in pain severity following the application of various treatments under similar conditions.

The visual analogue scale is widely used in various pathologies, for example rheumatic diseases, in patients with chronic pain, cancer (Hjermstad et al., 2011) or cases of allergic rhinitis (Klimek et al., 2017). In addition to pain assessment, it is used to assess quality of life (Seene & Kaasik, 2012), asthma, dyspepsia and ambulation (Delgado et al., 2018; Gould et al., 2001). It is a simple, valid and effective tool to assess disease control (Klimek et al., 2017).

Interpretation of results by numerical association (Haefeli & Elfering, 2006) allows the possibility of conducting statistical studies. Interpretation of the results followed the following standardization: 0- no pain, 1-3 mild pain, 4-7 moderate pain, 8-10 severe pain.

6.8.4. Joint testing

The joint balance or testing is the first functional assessment from the battery of tests used. It evaluates the articular mobility of the patient with neuro-motor impairment and is of particular importance for establishing the goals of functional rehabilitation in order to eliminate dysfunctions of the movement scheme and prevent the installation of redos/retracts. It is useful in order to specify the needs of orthotics or assistive devices to be used by the patient, identifying the progress or the stationary status following the application of the treatment.

The evaluation of the range of motion in the ankle, knee and hip joint was performed by goniometry. The articular balance not only measures the angles of movement but also assesses the final sensation - end-feel (Morin, 2018; Tudor Sbenghe, 2002, p. 136) after going through the entire articular amplitude. Mobilization of the painful joint can cause the pain to appear before reaching the possible range of motion of the joint, indicating an acute inflammatory process, simultaneously with reaching the possible AM, indicating a subacute process or when applying additional tension, indicating the chronic stage.

The joint balance tests flexion/extension (pendulum) or abduction/adduction (oscillating) movements and joint congruence, recording abnormal movements or in non-physiological directions.

Maximum normal values (Braddom, 2011, p. 31-32) of the range of motion (degrees) considered therapeutic evaluation targets, as well as the positioning of the goniometer are shown as follows:

- For ankle and foot: normal mobility register - plantar flexion 0-50 degrees, dorsiflexion 0-20 degrees, total amplitude 70 degrees, subject position - supine; mobility plan - sagittal; arrangement of the goniometer - the axis is located under the lateral malleolus, the fixed arm is kept along the fibula, the mobile arm is kept parallel to the V metatarsal;
- For the knee: normal mobility register - flexion 0-135 degrees, subject position - ventral decubitus, sagittal mobility plane, arrangement of the goniometer - the axis is located on the

side of the knee, the fixed arm is kept at zero degrees, the mobile arm follows the side lateral side of the fibula;

- For the hip: normal mobility register - flexion 0-90 with the knee extended and 0-120 with the knee in flexion, subject position - supine, sagittal mobility plane, goniometer arrangement - the axis is centered on the lateral face of the lower limb, at the level of the greater trochanter, the mobile arm is kept parallel to the lateral face of the femur.

Increased range of motion can be passively induced by the physiotherapist and if the determined active mobility is greater than the passive one, the subject registers a significant decrease in muscle strength (Tudor Sbenghe, 2002, p. 136-137).

6.8.5. Muscle testing - MRC scale

The muscle evaluation is always performed after the joint balance.

Muscle evaluation through muscle testing has a role in specifying the diagnosis and provides clues on the value of muscle strength, the value of muscle resistance, the size of muscle tone, the quantification of muscle innervation, the level of motor control, the anatomical integrity of the muscles.

In the recuperative program, the available muscle value determines the therapeutic program and the way in which daily activities are affected so that muscle imbalances that generate misalignments can be prevented. The need for assistive devices is appreciated, which activities can be carried out based on the remaining muscle, the need for muscle re-education and the vocational possibilities are indicated.

The objective evaluation includes inspection and palpation - muscle hypotrophy and hypotonia, differentiation from edema of the lower limbs, muscle symmetry.

The passive movement of the segments distinguishes pyramidal spasticity - the knife blade sign from extrapyramidal stiffness - the cog wheel sign, control of coordination and balance. Muscular strength is defined as muscle contraction against a resistance. Muscle strength can also be reproduced by the tension of a contracted muscle. The MRC grading system includes the range 0-5, with ten qualifications (Fisher & Harrington, 2015; Tudor Sbenghe, 2002, p. 190), according **Tabel 6.1**.

Tabel 6.1 Muscle testing - MRC units, *adaptation after* (Fisher & Harrington, 2015; Tudor Sbenghe, 2002, p. 190)

MRC Rank	Qualification	The strength	Endurance
5	Normal	It expresses a full movement against gravity while applying strong resistance	All current activities can be performed without the onset of fatigue
4	Good	Idem 5, moderate resistance	Idem 5
3+	Moderate +	Idem 5, light resistance	Limited endurance, fatigue sets in quickly
3	Moderate	It expresses a complete movement against gravity	The patient performs limited daily activities; if all the lower limbs muscles register force 3, it becomes impossible to gait sustain.
3-	Moderate -	Movement against gravity is possible at half the normal amplitude	Idem 3 but more emphasized
2+	Poor +	Antigravitational movement located below the threshold of 50% of the movement amplitude	Mechanical assistance is required to carry out partial current activities
2	Poor	Full movement without the influence of gravity	Idem 2+
2-	Poor -	Partial motion excluding gravity	Complete dependence, the patient cannot perform any current activity
1	Sketched	There is no movement, but you can feel the contraction at the level of the tendon	Idem 2-
0	Null	There is no contraction	Idem 2-

The muscle balance evaluates a maximum force relative to the tested segment with the manual muscle testing method, described by the National Foundation for Infantile Paralysis in 1946 – L. Daniels & C. Warthingham. Force 3 was established as the threshold that defines resistance against gravity, delimiting patients with severe incapacity compared to those with normal capacity - the idea of excellence of Professor Robert Lovett from Harvard University in 1912. By applying additional resistances in the progressive rehabilitation of patients, it is possible to personalize their normality of movement. Muscle testing involves positioning adapted to each muscle group to exclude gravity (force 0-1-2) or to consider gravity (force 3-4-5), with or without additional resistance (Avers & Brown, 2019; Tudor Sbenghe, 2002, p. 191).

According to the medical protocol for physical medicine and rehabilitation, legislated by Order no. 534 /22.04.2021, published in the Official Gazette, Part I no. 439/26.04.2021, muscle strength testing (MRC scale) is performed bilaterally, being a clinical scale with 6 levels (0-5). Bioelectrical impedance can also be used as a way to evaluate striated muscles and peripheral nerves, by determining the body composition of each patient. The MRC scale calculates commensurate force for muscle groups related to the upper limbs taking into account arm abduction, forearm flexion and fist extensions and for the lower limbs thigh flexion, knee extension and leg dorsiflexion.

6.8.6. Muscle imbalances

Muscular imbalances were evaluated with the static horizontal pedal system and were expressed in average analog values for the right and left lower limb, highlighting the differences between them according to the values transmitted by the sensors.

In parallel, the muscle strength in MRC units related to the injured muscle group was determined before and after the rehabilitation program.

6.8.7. Target heart rate

The target heart rate was determined by taking into account the maximum heart rate, based on the heart rate reserve according to Karvonen's formula (Tudor Sbenghe, 2002, p. 569; Wood, 2010). The maximum heart rate was calculated as the difference between 220 – the patient's age to establish its upper limit.

The heart rate reserve or the target heart rate related to the recovery program using the Karvonen formula has as its starting point the resting heart rate to which is added the difference between the maximum heart rate and the resting heart rate multiplied by the intensity of the effort expressed as a percentage as follows:

Heart rate (FC) target = [(FC maximum - FC of rest) ×% Intensity] + FC of rest, respectively **FCT= [(FCM-FCR)*I (%)] + FCR** **(6.1)**

A gradual intensity of 40-60% was proposed, in this way not exceeding the lactate threshold. Taking as a reference resting HR = 60 bpm, target heart rate values would vary between 108 bpm and 168 bpm, for a person aged 40 years, for whom HR max = 180 bpm, as follows:

-Phase I of rehabilitation, 40% intensity effort; FCT I = (180-60)*40% + 60 = 108 bpm (60% of maximum heart rate)

-Phase II of rehabilitation, effort with 50% intensity; FCT II = (180-60)*50% + 60 = 120 bpm (66.67% of maximum heart rate)

-Phase III of rehabilitation, effort with 60% intensity. FCT III = (180-60)*60% + 60 = 168 bpm (93.34% of maximum heart rate)

Heart rate monitoring was carried out with the Huawei Watch GT 2 Smartwatch (HUAWEI, 2021), equipped with an optical sensor for heart rate measured throughout the course of each physical therapy session - **Figure 6.1**. The highest value recorded on the corresponding intensity step was registerd.

Figura 6.1 Smartwatch Huawei Watch GT 2, equipped with an optical sensor for heart rate (HUAWEI, 2021)

6.8.8. BORG Perceived Effort Scale

The Borg scale (**Table 6.2**), graded from 1 to 10, reveals the perception of pedaling effort and was used to establish the initial basic pace that corresponds to an intensity level agreed by the patient, the conditioning being aerobic (Borg, 1982; Scherr et al., 2013). For rehabilitation, the level of perceived effort must not exceed the moderate level: Borg = 4-6, in order not to reach the lactate threshold (Kang et al., 2003).

Tabelul 6.2 Scala Borg în pedalare, după (Kang et al., 2003; Wattbike, 2022)

Scale	Type of perceived effort	Rehabilitation area/ training	Purpose	Physiological adaptations	Actions	Average power (%)	Average heart rate (%)
1	**Very easy activity**	**Zone 1**	**Active recovery**	Increasing blood flow to muscles to remove metabolites and deliver nutrients	Promotes recovery and response to recovery training	< 55	< 68
2-3	**Easy activity**	**Zone 2**	**Endurance**	It improves lipid metabolism and the ability to use oxygen, produces power and increases efficiency. Increases energy economy	More efficient use of energy. Able to produce more power with the same level of effort, focuses on technique/skill	56-75	69-83
4-6	**Tempo/ Moderate**	**Zone 3**	**Tempo**	Improves carbohydrate metabolism, gives fast-twitch muscles the muscle characteristics of slow-twitch muscles	Improved lasting power	76-90	84-94
7-8	**Vigorous activity**	**Zone 4**	**Lactate threshold**	Improves carbohydrate metabolism, increases lactate threshold, changes some fast-twitch muscles to slow-twitch	Improved sustained race pace, useful during decline or pre-race periods: too much time in this zone can cause fatigue	91-105	95-105
9	Very hard activity	Zone 5	V0₂max/Speed	It improves the capacity of the cardiovascular system and VO_2max, increases the production of anaerobic energy and accelerates the elimination of metabolites	Improved cardiovascular and respiratory capacity and short-term fatigue resistance	106-120	>106
10	Maximum effort activity	Zone 6	Anaerobic capacity/ Neuromuscular/ Strenght	Increases maximum muscle power, develops cardiovascular system and VO_2max, increases lactate threshold	Sprint speed, the ability to accelerate	121-150	N/A

For post-Covid-19 patients, according to the physical medicine and rehabilitation medical protocol, legislated by Order no. 534/22.04.2021, published Official Gazette Part I no. 439/26.04.2021, follow-up of patients regarding the perceived effort during the rehabilitation program is required. The scales used evaluate fatigability, dyspnea and the effort required to perform an activity. Very useful in monitoring patients are the clinical signs: blood pressure and heart rate that can be determined with the thesiometer, respiratory rate, heart rate, as well as peripheral blood determinations related to the pulse and oxygen saturation, evaluated with the pulse oximeter. The cycle ergometer was recommended for cooperative patients in the specified recovery protocol - **Table 6.3** (EMITENT MINISTERUL SĂNĂTĂȚII, 2021).

Tabelul 6.3 Perception of effort/dyspnea - Borg Scale, după (MINISTERUL SĂNĂTĂȚII, 2021)

Perception of effort/dyspnea - Borg Scale	Borg scale interpretation – perceived effort	Dyspnea perception scale	Borg scale interpretation – perception of dyspnea
0	Without effort	0	No dyspnea
0.5	Very very easy	0	No dyspnea
1	Very easy	1	Vaguely perceptible
2	Easy	2	Very easy
3	Moderate	3	Mild to moderate
4	Not very intense	4	Moderate
5	Not very intense	5	Minimal breathing difficulties
6	Pretty intense	6	Moderate to severe
7	Pretty intense	7	Severe
8	Very intense	8	Very severe
9	Very very intense	9	Maximum lack of air
10	Maximum	10	Extreme shortness of breath

A maximum score of 4/10 on the Borg scale for perceived exertion/fatigue/dyspnea according to the post-Covid rehabilitation protocol is recommended in the rehabilitation of patients in the post-acute stage (EMITENT MINISTERUL SĂNĂTĂȚII, 2021).

I note that every patient had at least one mild to moderate COVID-19 episode that did not require hospitalization or oxygen therapy, eight patients being vaccinated and two patients not vaccinated.

CHAPTER 7. DESIGN AND CONSTRUCTION OF THE INNOVATIVE STATIC HORIZONTAL PEDAL DEVICE

7.1. The ergonomic design of the stationary horizontal bicycle

The design took into account the reliability of the device, the inter-pedal distance - optimally expressed by the auto-selected Q factor, the position of the patient, the mode of action and the distribution of forces in the controlled kinetic chain.

a. The importance of the Q factor (QF)

The design of the kinetotherapeutic device took into account ensuring its stability, considering the medical Q factor indicated for the rehabilitation of the lower limbs involving triple flexion/extension. Q-Factor (QF) in cycling or inter-pedal width is analogous to stride width in walking. Step width size has been shown to reduce the maximum knee abduction moment (Thorsen, 2018).

QF in cycling is directly correlated with stride width during ambulation. In normal gait, the preferred step width has been reported to be between 7-12 cm (Helbostad & Moe-Nilssen, 2003; Hollman et al., 2011; Thorsen, 2018; Wert et al., 2010) and between 13-17 cm when going up the stairs and 15-17 cm when going down the stairs (Paquette et al., 2014; Thorsen, 2018; Wert et al., 2010; Yocum et al., 2018).

The range of a mechanically efficient QF is expressed by the inter-pedal distance of 137-150 mm. The stationary bike was designed to use the natural locomotion capability of the human body to provide assisted movement. The self-selected QF decreases knee variability and improves stability, with a reported mean of 142 ± 12 mm, optimal 142 mm, and a very high knee variability reduction correlation statistically determined $R^2 = 0.938$ (B. X. Disley & Li, 2014; Thorsen, 2018).

Bicycle kinematic instability must be addressed to reduce the risk of knee injury. A change in the Q factor, i.e. the horizontal distance between the pedal arms, has been shown to decrease the metabolic cost. The Q factor has a combined effect on the gross mechanical efficiency and variability of the knee. The self-selected Q factor offering the highest efficiency and least variability at the knee measured 142 mm (14.2 cm) provided the best knee stability compared to other Q factors. The self-selected Q factor – **Figure 7.1**, has the potential to reduce the risk of knee injury and provide increased efficiency during pedaling (Benedict Xavier Disley & Li, 2014).

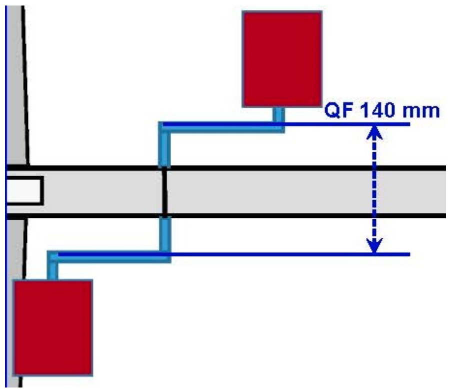


Figure 7.1 Self-selected QF [own contribution]

The built stationary bicycle has a self-selected QF = 14 cm. The TECHFIT Ped2 pedal board was used for the medical rehabilitation of the lower limbs to maintain the stability of the knee during pedaling.

b. Position of the patient

The patient's position is supine, with the trunk raised to 30-45% depending on the pathology.

Particularities regarding the safety of the device and the patient in supine position:
1. supine in long sitting with the lower limbs stabilized on the pedals by two support straps;
2. adjusting the length using the upper limb stabilizer bar so that the knee is slightly flexed (about 10 degrees) when the leg is at the lowest point of the pedaling cycle and ensuring that the patient can pedal throughout the cycle ;
3. the foot support straps on the pedal are flexible, they stabilize the foot while at the same time allowing the movement of the ankle joint during pedaling;
4. the support bar for the upper limbs will help to strengthen the balance reaction in long sitting.

c. Mode of action

The movement is active with the following characteristics:
1. controlled movement of the pedal back and forth to the end/restriction by a half or a quarter turn in the case of SNC/SNP conditions with severe motor deficits;
2. the emphasis can be changed on the movement of the hip, knee or ankle by changing the distance from the pedals.

d. Movement - distribution of forces in a controlled kinetic chain

The built pedaling system is based on the stabilization of the kinetic chain by fixing the legs with two support bands, one at the level of the calcaneus and the other on the dorsal side of the legs. The load is represented by the weight of the lower limbs, the muscular pushing force used against the resistance of the pedal configures the system as a controlled kinetic chain. It involves the use of the three joints (hip, knee, ankle) in a rotating sagittal plane, with a consolidated balance reaction in long sitting (dorsal recumbency).

e. Horizontal pedalboard scheme - side and top view - Figure 7.2., Figure 7.3. (Annex no. 2 and Annex no. 3)

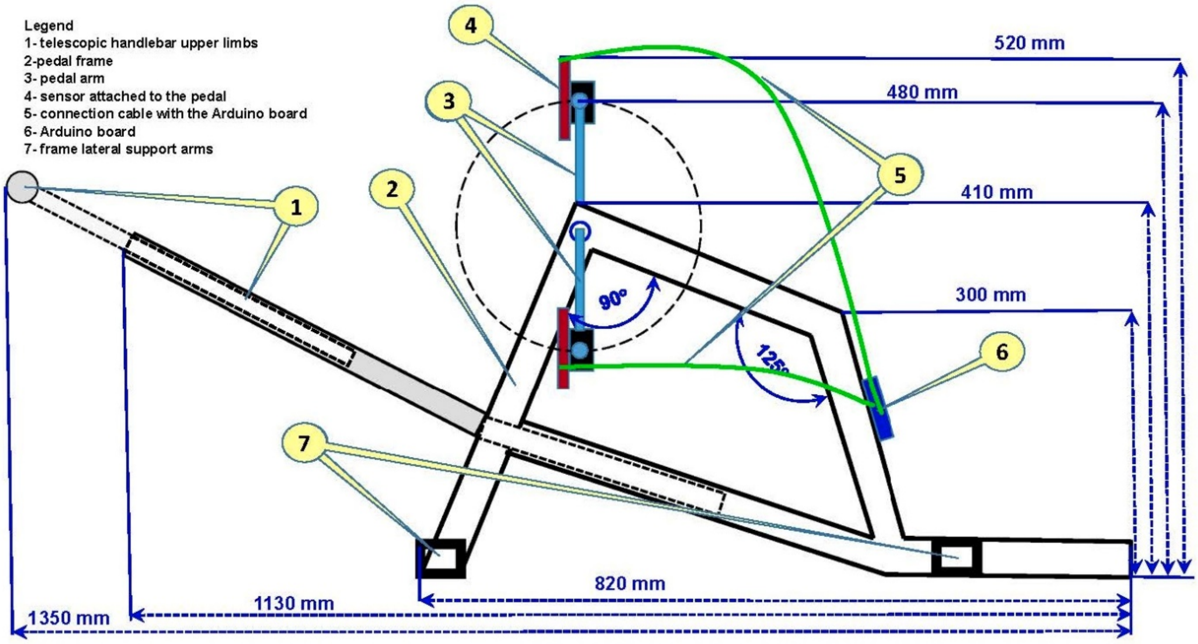


Figure 7.2 Diagram of horizontal pedalboard - side view [own contribution]

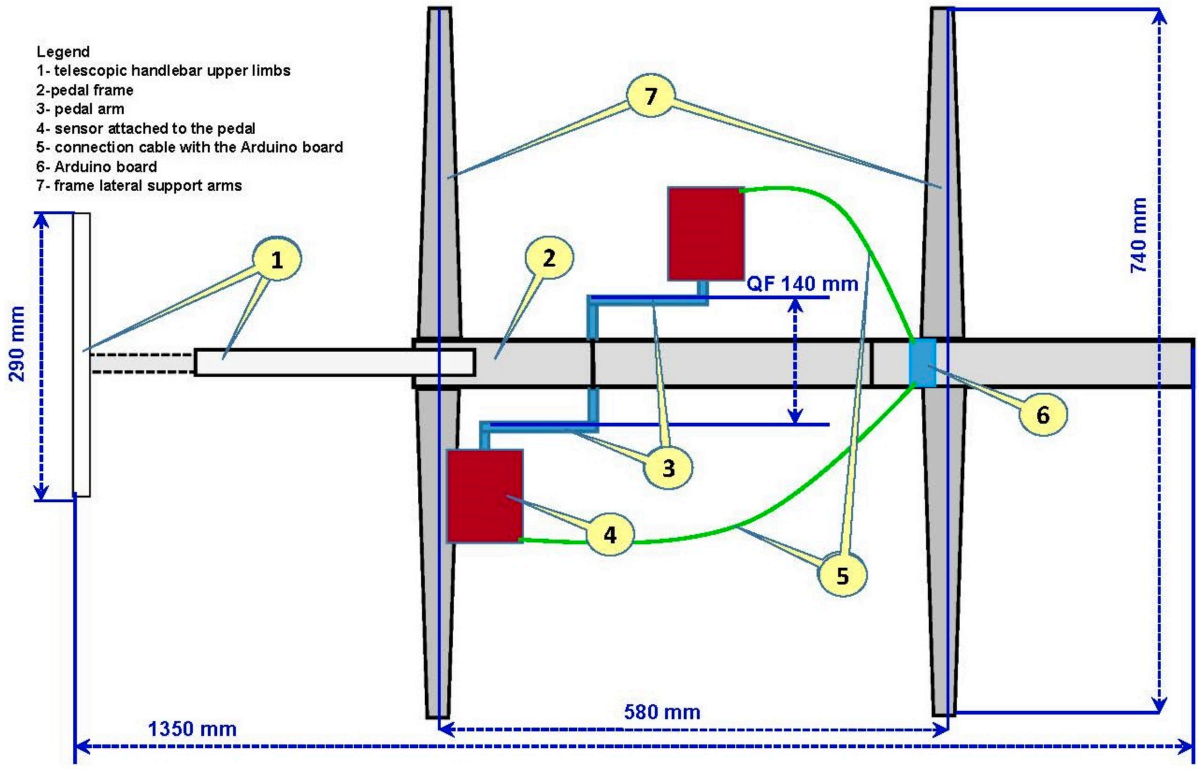


Figure 7.3 Diagram of horizontal pedalboard - top view [own contribution]

7.2. Electrical scheme design

The design of the electrical scheme took into account ensuring the safety of the use of an electrical system. For the transfer of the information from the plantar pressure sensors, the analog board Arduino was used, whose reliability, usefulness, efficiency in gait analysis was demonstrated by the specialized literature. Added to this is the low cost, being a feasible method of design and application (C. Drugă 1, 2017; Grenez et al., 2013; Jor et al., 2019).

Instruments used to measure variables

a. Pressure measurement systems.

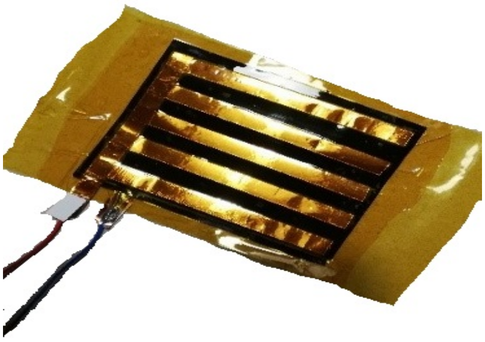
The pressure is equal to the force divided by the square of the area being measured by the pressure sensors. Therefore, the pressure is equal to the force divided by the area of the sensor. The plantar pressure measurements used are those of foot-pedal contact.

Pressure sensors can be used to determine kinetic chain imbalances, biomechanics and postural alignment, to establish the effectiveness of orthoses and the risk of injury in the diabetic foot, and for post-operative rehabilitation.

Plantar pressures are measured using sensors attached to the pedals. The sensor signals are converted into analog values for both legs.

FSRs (Force Sensing Resistor) are resistance pressure sensors used in all kinds of industries (medical, electronics, mobile phones, portable gaming devices), easy to use for pressure detection.

The FSR is connected to a 10Kohm resistor and the sensor is read on analog pin 0 and 1 respectively for each leg separately – **Figure 7.4.**



Kapton tape	
Copper strip	
Velostat conductive film	
Velostat conductive film	
Copper strip	
Kapton tape	

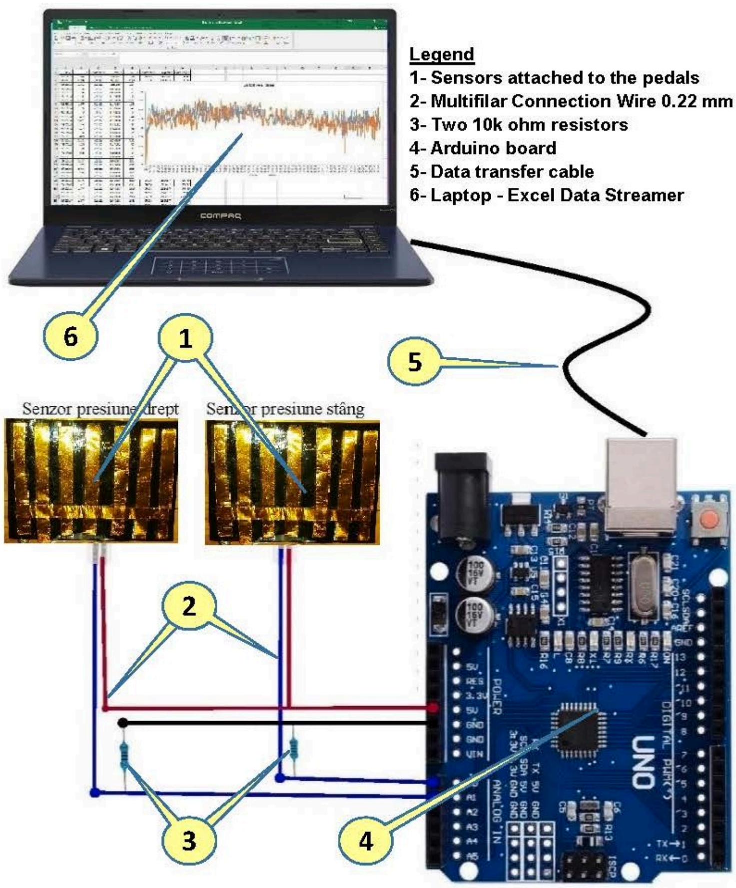
Figure 7.4 Pressure sensor built for pedals [own contribution]

Measure the reaction forces according to the output of the analog sensor. Using the USB connection cable between the Arduino board and the computer, the analog value is retrieved.

a. Electrical diagram

The wiring diagram includes the following main components **- Figure 7.5:**

- Two 10k ohm resistors;
- Arduino UNO R3 CH340 board for autologous signal;
- **FSR**- Force Sensing Resistor pressure sensors attached to the pedals;
- USB data transfer cable to the computer;
- Connecting cables, insulators, velostat, kapton.




```
const String kDelimiter = ",";   // Data Streamer expects a comma delimeter
// SETUP ----------------------------------------------------------------------
void setup() {
  // Initializations occur here
  Serial.begin(9600);
}
// START OF MAIN LOOP --------------------------------------------------------
void loop()
{
  // Read sensor values
  int leftfootReading = analogRead(A0);
  int rightfootReading = analogRead(A1);

  // Send data out separated by a comma (kDelimiter)
  Serial.print(kDelimiter); //first column reserved for commands
  Serial.print(leftfootReading);
  Serial.print(kDelimiter);
  Serial.print(rightfootReading);
  Serial.print(kDelimiter);
  Serial.println(); // Add final line ending character only once
  delay(10); //delay 10 millisecond before looping again
}
```

Figure 7.5 Sensors electrical circuit, **Arduino board-PC connection** [own contribution]

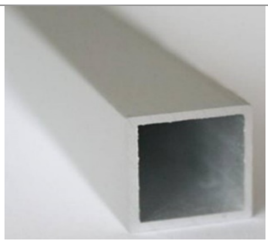
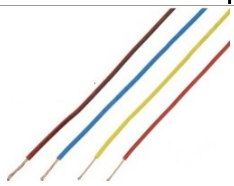
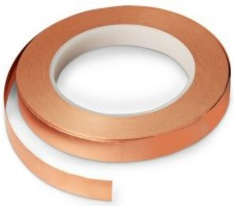
The program used in C++ is highlighted in **Annex no. 6**.

7.3. The actual construction of the horizontal bicycle and the wiring diagram

The materials were chosen so that the weight is as low as possible but does not interfere with the stability of the device and the safety of use is maximum.

a. Necessary materials are detailed in Table 7.1 accompanied by the technical specifications. (Figures 7.6-7.16)

Table 7.1 Specifications on the materials used

Nr crt.	Nume produs	Specificaţii
1	 **Figure 7.6 Pedalier**	**TECHFIT Ped2 pedal with display** Digital display: time, repetitions, calories, revolutions per minute Packaged product size: 38 cm x 18 cm x 35 cm (LxWxH) Net weight: 2.35 kg Levels of difficulty: 5 Braking mechanism: mechanical (Techfit.ro, 2021).
2	 **Figure 7.7 Aluminum profile**	**Square aluminum profile 40 mmx 40 mmx3m white** Square aluminum profile 40x40 x 3m Medium durability aluminum square tube Chemical composition according to: EN 537-3 Mechanical properties according to: EN 755-2 Indications for fine mechanics (Webshop.mam-bricolaj.ro, 2021).
3	 **Figure 7.8 Connection wire**	**Multifilar Connection Wire 0.22 mm^2 – Blue, Black, Red,** Brown Multifilar, wire section: 0.22 mm^2 Insulation: PVC Nominal voltage: 150 V Outer diameter: 1.3 mm (Robofun.ro, 2021c).
4	 **Figure 7.9 Kapton tape**	**Self-adhesive insulating tape Kapton tape 80mm x 30m** This tape is ideal for soldering, insulating board circuits, protecting against high temperatures, for different electrical insulators, effective at separating electrical heating resistors, etc. Length: 30 m Width: 80 mm The maximum temperature it withstands is 280° Celsius (Emag.ro, 2021a).
5	 **Figure 7.10 Copper tape with adhesive**	**Copper tape with adhesive - 6mm x 15 meters** It is characterized by flexibility. It is used when gluing the sub-components of a system. It conducts electric current with small loads on one side. The thickness is 0.07 mm and the width is 6 mm.(Robofun.ro, 2021b).
6	 **Figure 7.11 Velostat**	**Conductive foil with variable resistance with pressure - Velostat, size 30x30 cm** Conductor used for portable type sensors - flexible, reacts to pressures, being resistant to temperatures from -45°C to 65°C, heat-tight Dimensions: 30x30 cm / piece; Thickness: 4 mil / 0.1mm; Volume Resistance: <500 ohm-cm; Surface resistance < 31,000 ohms/cm2 (Emag.ro, 2021b).

7	 **Figure 7.12 Arduino UNO transparent plastic case**	**Arduino UNO transparent plastic case** The Arduino Uno R3 development board is protected by the acrylic case. The case is made of transparent plastic, being joined by 2 components. Adapted for all types of arduino boards and UNO columns. Provides access to the reset button and pins. Assembly is easy with the help of the instructions on the case. It provides stability and protection to the Arduino UNO development board. The connection with the USB cable, the power supply and the access to the reset button are easy to achieve. The size is reduced: length 80 mm, width 65 mm and height 18 mm. It is a light device, weighing 45g(Sigmanortec.ro, 2021).
8	 **Figure 7.13 Arduino UNO R3 CH340**	**Arduino UNO R3 CH340** UNO R3 development board + USB cable It is compatible with Arduino - an open-source processing platform. The Uno R3 development board is a version of the Uno with a new and improved USB interface. It has an expansion slot with support for 3.3 V, a RESET pin and an automatic selection system for the USB or DC power source. General characteristics: Processor type ATmega328, Voltage: 5V; Broadcast frequency: 16 MHz (Robofun.ro, 2021a).
9	 **Figure 7.14 Two-component adhesive**	**Universal two-component adhesive - Bison Epoxy** It is durable, being produced from epoxy resins with a gray color, adapted to the repair of metal objects. It resists immersion in water, torsional forces, varying temperatures, vibrations of any type and pressure, It is indicated for repairing parts of bicycles, cars and any other metal object. It was used for filling capacity, 1 tube having 240 cm2,(Dedeman.ro, 2021a)
10	 **Figure 7.15 Self-tapping screw for sheet metal**	**Sheet metal self-tapping screw, flat washer, steel, white zinc-plated, 4.2 x 25 mm** The screw is made of steel with a white zinc finish and is intended for use in sheet metal fixings. This is self-tapping, has a flat head, PH2 imprint, diameter of 4.2 mm and length of 25 mm, made of steel (Dedeman.ro, 2021b)
11	 **Figure 7.16 Hama USB 2.0 cable**	**Hama USB 2.0 cable, gold-plated, 1.5 m** High Speed data transfer up to 480 Mbps; elegant and flexible fabric cover for extra protection against bending; It presents safety when transmitting the signal, it is resistant to contact; Double shielding for optimal reduction of disruptive electromagnetic interference. General characteristics Product type USB 2.0 cable Length (m) 1.5 Transfer speed 480 MBit/s USB A - USB B connector type Other details Use: PC & Notebook (Altex.ro, 2021)

Other materials used were: two 10kohm resistors, polyurethane foam, tin for soldering, universal glue, screws with nuts and a handlebar type bar to support the upper limbs while pedaling.

b. The construction stages of the stationary horizontal pedal system were as follows:

b1. The movable arms of the TECHFIT Ped2 bottom bracket with display were removed and replaced with arms constructed from longer aluminum profile, which were later filled with polyurethane foam. **(Figure 7.17)**

Figure 7.17 Arms made of aluminum profile attached to the pedal [own contribution]

b2. Self-tapping sheet metal screws, flat head, washer, steel, white zinc plated, 4.2 x 25 mm, were used to fix the angles of the aluminum profile. **(Figure 7.18)**

Figure 7.18 Fixing the angles of the aluminum profile with self-tapping screws for sheet metal [own contribution]

b3. Attaching the lateral support arms to the pedal frame with biocomponent adhesive and self-tapping screws. **(Figure 7.19)**

Figure 7.19 Attaching the side support arms [own contribution]

b4. The support devices - the hard pedal platform, for the pressure sensor, built from MDF material with the help of screws with nuts and universal glue, were mounted **(Figure 7.20**).

Figure 7.20 Support devices - hard pedal platform for pressure sensor - MDF [own contribution]

b5. Construction and installation of the central balancing axis and telescopic handlebar support. (**Figure 7.21)**

Figure 7.21 Construction and installation of the central axis for balancing and supporting the telescopic handlebar [own contribution]

b6. Building and mounting the sensor on the hard MDF platform of the pedal

When building and mounting the sensors on the hard MDF platform of the pedal, kaptan was used as an insulating material over which self-adhesive copper strips were glued (7 parallel strips and a strip perpendicular to the front end), after which they were tinned, thus building two statures having in the middle two conductive velostat foils (Emag.ro, 2021b). The calculated area of the sensor surface is 80mm*95mm=760 mm2 – **Figure 7.22**.

Figure 7.22 Building and mounting the sensor on the hard MDF platform of the pedal [own contribution]

b7. Mounting the straps to support the foot on the pedal at the level of the calcaneus in the Achilles area and at the level of the dorsal face of the foot - **Figure 7.23**.

Figure 7.23 Foot straps on the pedal [own contribution]

b8. Assembling the case and the Arduino UNO R3 CH340 board and stabilizing them with two self-tapping screws – **Figure 7.24.**

Figure 7.24 Assembly of the Arduino UNO R3 CH340 board [own contribution]

b9. Entire horizontal pedal assembly - **Figure 7.25.**

Figure 7.25 Entire horizontal pedal assembly [own contribution]

7.4. Verifying the functionality of the device

The open-source Arduino software (IDE 1.8.19) makes it easy to write code and upload it to the board. This software can be used with any Arduino board (Arduino.cc, 2021).

Microsoft Excel is a useful tool for viewing and analyzing data with the help of the Data Streamer application that allows importing, viewing and analyzing live data from external devices, such as the Arduino microcontroller. This way sensor data collection is accessible and easy to use for a wide variety of applications. A C++ program was used according to **Annex no. 6.** Data Streamer, free with O365, reads values printed on the computer's serial port, with the data printed on the Arduino IDE serial monitor (Microsoft.com, 2021).

The pressure sensor attached to the pedal is connected to the Arduino board. With the help of a USB cable, the data is transmitted to the PC for real-time reproduction of the pedaling in Microsoft Excel performed with the Data Streamer. The test was performed with hand pressure to verify data transmission and calculate the margin of error. The resulting values are transmitted at intervals of 150 ms on 500 lines - **Table 7.2, Figure 7.26**.

Table 7.2 Real-time Data Streamer data transmission *(excerpt)*

Timp	Senzor stâng Seria 1	Ajustare marja A0	Valoare analoagă A0	Senzor drept Seria 2	Ajustare marja A1	Valoare analoagă A1	Diferenţe A0-A1
59:05.3	114	22.12	91.88	105	6.63	98.37	-6.49
59:05.3	121	22.12	98.88	114	6.63	107.37	-8.49
59:05.3	127	22.12	103.88	119	6.63	112.37	-8.49
59:05.3	130	22.12	107.88	123	6.63	116.37	-8.49
59:05.4	136	22.12	113.88	130	6.63	123.37	-9.49
59:05.4	136	22.12	113.88	124	6.63	117.37	-3.49
59:05.4	139	22.12	116.88	141	6.63	134.37	-17.49
59:05.4	142	22.12	119.88	149	6.63	142.37	-22.49
59:05.4	144	22.12	121.88	161	6.63	154.37	-32.49
59:05.4	147	22.12	124.88	164	6.63	157.37	-32.49
59:05.5	148	22.12	125.88	174	6.63	167.37	-41.49
59:05.5	149	22.12	127.88	167	6.63	160.37	-33.49
59:05.5	151	22.12	128.88	181	6.63	174.37	-45.49
59:05.5	155	22.12	132.88	187	6.63	180.37	-47.49
59:05.5	158	22.12	135.88	197	6.63	190.37	-54.49
59:05.5	158	22.12	135.88	189	6.63	182.37	-46.49
59:05.5	161	22.12	138.88	203	6.63	196.37	-57.49
59:05.5	163	22.12	140.88	207	6.63	200.37	-59.49
59:05.5	167	22.12	144.88	209	6.63	202.37	-57.49
59:05.6	168	22.12	145.88	218	6.63	211.37	-65.49
59:05.6	168	22.12	145.88	214	6.63	207.37	-61.49
59:05.6	171	22.12	148.88	223	6.63	216.37	-67.49
59:05.6	176	22.12	153.88	227	6.63	220.37	-66.49
59:05.6	177	22.12	154.88	231	6.63	224.37	-69.49

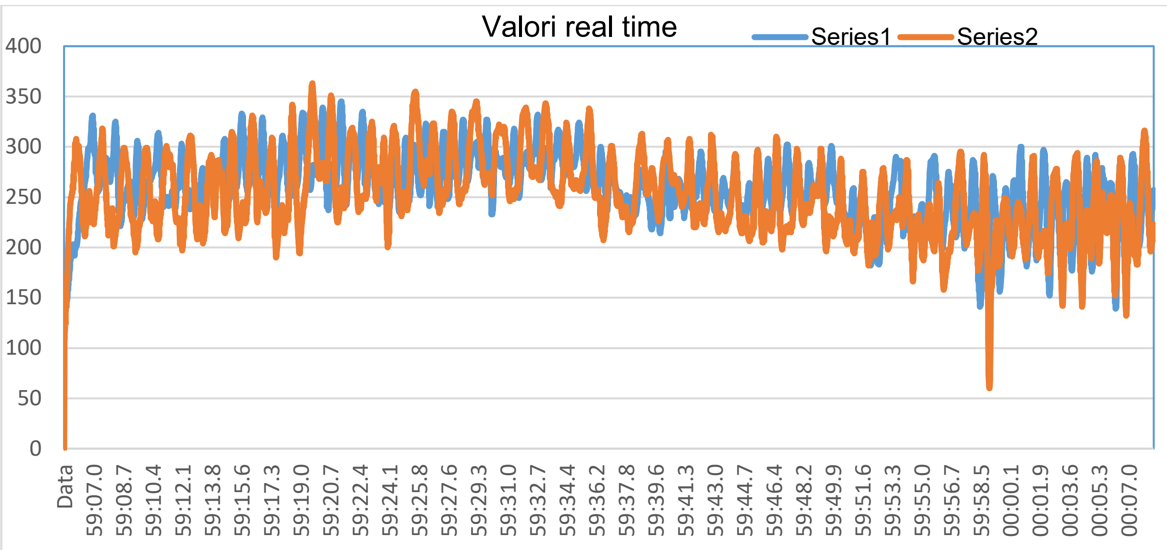


Figure 7.26 Left (series 1) and right (series 2) pedal sensor graph [own contribution]

The test lasted 5 minutes, the highest recorded analog values being 345 and 253 (manually tested values), therefore the system works and the next preliminary level can be implemented.

The Arduino board returns a value from 0-1024 for any given analog signal corresponding to a 5 volt source.

The testing of the sensors attached to the pedals with different weights were carried out with load tests, the sensor being in contact with the ground in an orthostatic position, involving standard weights of 6,8,10,12,16, 20 kg and respectively healthy subjects according to Table 7.3. From the weight of 123 kg + the analog signal remains constant at 1023 - Figure 7.27. I mention that the highest weight recorded in the patients selected for the present research was 104.1 kg, so the sensors can be used for the preliminary and final study.

Table 7.3 Testing sensors attached to pedals with different weights *[own contribution]*

Type	Weight (kg)	Average analog value
standard	6	55
standard	8	74
standard	10	92
standard	12	111
standard	16	148
standard	20	185
person	60	554
person	66	610
person	72	665
person	78	721
person	87	804
person	93	859
person	99	915
person	105	970
person	123	1023
person	150	1023
person	180	1023

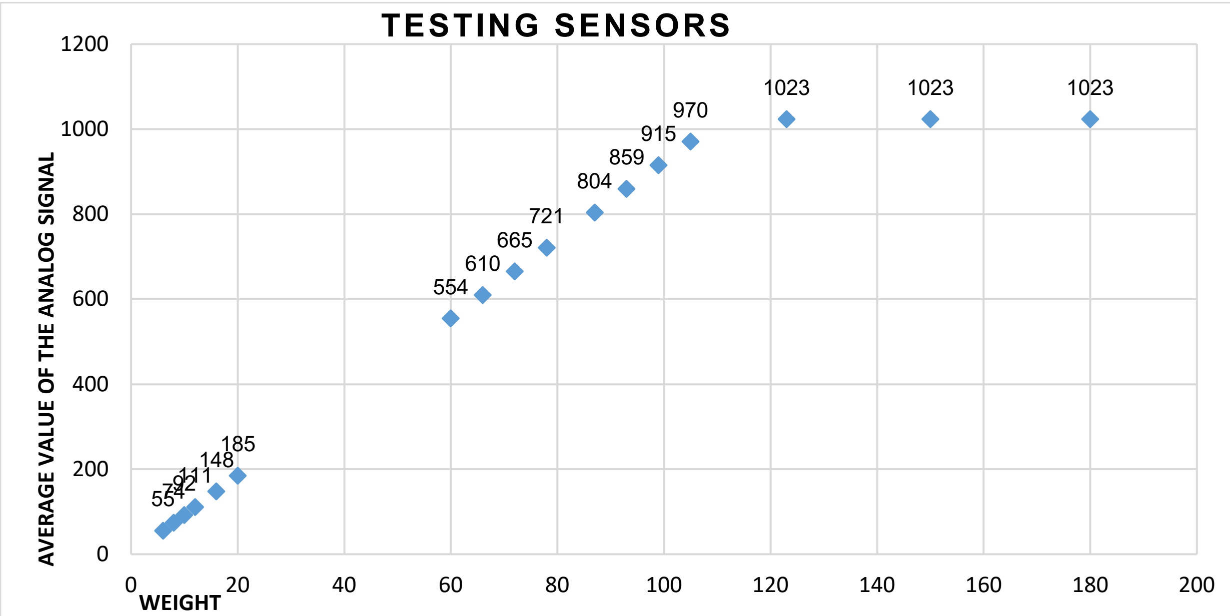


Figure 7.27 Testing sensors attached to pedals with different weights [own contribution]

Eliminating the last 2 capped values, the linear regression equation was calculated **y=8.9243x+10.496.** **(7.1)**

The size of the effect is R2=0.9949, that is, for 99.49% of the subjects and the tested weights, there is a significant link between them and the value displayed by the sensors. The values allowed for research projects must exceed 90%, the condition being fulfilled in this case - **Figure 7.28**.

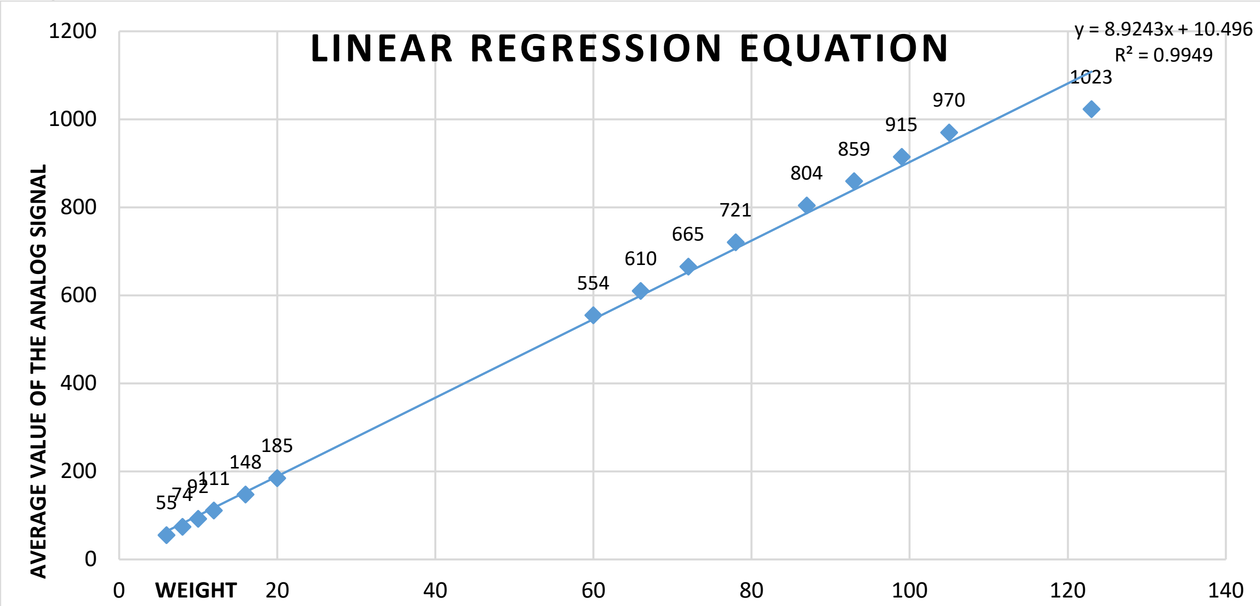
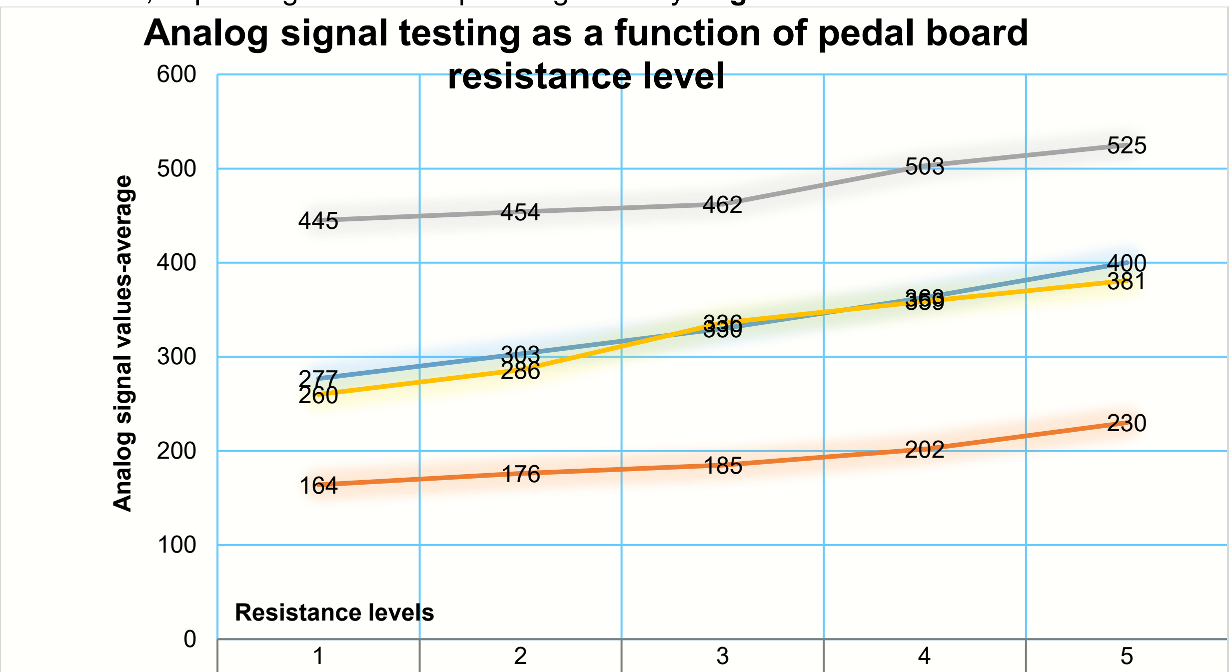


Figure 7.28 Linear regression equation [own contribution]

Later, we tested the values recorded by the sensors from a horizontal position while pedaling when the contact with the pedal is represented by the pushing pressure of a lower limb alternating with the opposite one, calculating an average value of the analog signal transmitted, depending also on the pedaling intensity- **Figure 7.29.**



	1	2	3	4	5
VAM B	277	303	330	363	400
VAM F	164	176	185	202	230
MAX VA B	445	454	462	503	525
MAX VA F	260	286	336	359	381

Figure 7.29 Analog signal testing as a function of pedal board resistance level [own contribution]

CHAPTER 8. MEDICAL REHABILITATION RELATING TO THE CONTROL GROUP AND THE EXPERIMENTAL GROUP IN VIEW OF AMBULATION FACILITY

8.1. Medical rehabilitation relative to the control group

8.1.1 Medical rehabilitation protocol related to the control group

The control group includes five subjects with the indication of physical therapy from the specialist doctor: a patient with damage to the coxo-femoral joint (right coxarthrosis associated with lumbosciatica), a patient with stroke and left hemiplegia, a patient with damage to the knee joint (gonarthrosis and associated comorbidities) and two patients with damage to the ankle joint (post-sprain, respectively post-fracture status). All patients had a history of an episode of COVID-19. The recovery program lasted 4 weeks with a frequency of 3 times a week, in total 12 sessions (50 min/session).

The major objectives regarding combating the effects of COVID-19 aimed (MINISTERUL SĂNĂTĂȚII, 2021):
- restoring cardio-respiratory capacity, improving exercise tolerance;
- improving the effects of deconditioning and their complications;
- prevention of neuro-motor and mental deficiencies;
- improving the quality of life by promoting physical and social functionality.

The general and specific objectives of each type of condition aimed at the following:

➔ **General objectives:**
1. Pain relief
2. Restoring mobility
3. Increasing joint strength and mobility
4. Prevention and correction of deformations
5. Patient education

➔**Specific objectives – coxarthrosis, lumbosciatica** (Braddom, 2011, p. 941, 945):
1. correct posture - postural and pelvic alignment, strengthening of the abdominal muscles and pelvic stabilizers (medial gluteal, gluteal mass), strengthening of areas characterized by contracture or stiffness (hamstrings, hip flexors and rotators);
2. prevention of deconditioning;
3. pain relief, functional improvement;
4. toning and increasing the resistance of the muscles that support the spine and improving flexibility in areas where it is deficient;
5. correct dosage of effort in fixed, planned steps, based on realistic goals and symptoms.

➔**Specific objectives – post-stroke** (Braddom, 2011, p. 1266):
1. the normal synchronization between muscle contraction and relaxation during exercise (the triceps surae contracts actively during the swing phase but fails to ensure stability during the support phase and the quadriceps muscle remains active throughout the walking cycle, including the of balance);
2. ideomotor maintenance of motor schemes;
3. prevention of deformations and vicious attitudes;
4. promoting the ability to control the movement made by a synergistic muscle or muscle group;
5. re-education of postural reactions and balance in basic positions.

➔**Specific objectives – post-trauma** (Braddom, 2011, p. 369)**:**
1. obtaining joint stability;
2. restoring muscle balance and mobility;
3. reconstruction of the leg alignment.n

8.1.2 Physiotherapy program adapted to the control group

The recovery program lasted 4 weeks with a frequency of 3 times a week, a total of 12 sessions (min 50 min/session). Each 50-minute session included distinct elements, according to **Table 8.1**:

Table 8.1 Detailed content of the physical therapy program adapted to the control group

Standard physical therapy program content adapted to each condition (minutes)	Gonarthrosis, Coxarthrosis lombosciatica (mechanical origin) 2 subjects	Ischemic stroke hemiplegia 1 subject	Status Post-trauma MI 2 subjects
Therapeutic massage	15	15	
Manual lymphatic drainage			15
Invessie table positioning	5		
Specific exercises*	20		
Postural treatment - Positions at the edge of the bed in short sitting (active-isometric)		5	
FNP – Kabat (5 min passive, 5 min active)		10	5
Passive, passive-active physiotherapy		10	20
Manual therapy & stretching	10	10	10
Total time (minutes) of which	**50**	**50**	**50**
-active	**20**	**5**	**15**
-passive	30	40	35
-active break (isometric)	0	5	0

*** Details of specific exercises**

-Gonarthrosis, Coxarthrosis and lumbosciatica of mechanical origin with associated lordosis - medical recommendation - Wiliams program**, 5-7-10 repetitions (progressive increases every 4 sessions, total 12 sessions)**

Specific exercises from the supine position

- bend and extend the knees alternately;
- flexion of the thigh on the abdomen is performed alternately, holding for 10 seconds, followed by returning with the lower limbs extended and then resuming the movement with simultaneous execution;
- hands on the back of the head, feet on the ground, perform thigh flexion on the abdomen alternately, hold for 10 seconds, followed by return with the lower limbs extended;
- with the arms stretched above the head and the knees bent, the lumbar area is pressed to the floor, contracting the abdominal muscles;
- with bent knees and feet on the ground, rotate the pelvis to the left, respectively to the right;
- with the lower limbs extended, place the heel on the opposite knee and leave the thigh on the ground, then return to the initial position;
- raise one leg above the ground, hold for 10 seconds, then return to the initial position;
- with a pillow under the head, hips and knees flexed, feet on the ground, contracting the gluteal and abdominal muscles, tilt the pelvis by lifting the buttocks off the ground. Gradually perform the same movements with the knees less and less bent.

-Stroke left hemiplegia, Status post-trauma lower limbs

Specific exercises

Neuroproprioceptive facilitation techniques were applied (Beckers & Buck, 2021, p. 145-166) passive, passive-active physical therapy, **5-7-10 repetitions (progressive increases every 4 sessions, total 12 sessions).**

Specific exercises:

- Flexion-abduction-internal rotation (Beckers & Buck, 2021, p. 145);
- Flexion-abduction – internal rotation with knee flexion (Beckers & Buck, 2021, p. 148);
- Flexion-abduction – internal rotation with knee extension (Beckers & Buck, 2021, p. 149);
- Extension-adduction-external rotation (Beckers & Buck, 2021, p. 151);
- Extension-adduction-external rotation with knee extension (Beckers & Buck, 2021, p. 154);
- Extension-adduction-external rotation with knee flexion (Beckers & Buck, 2021, p. 156);

- Flexion-adduction-external rotation (Beckers & Buck, 2021, p. 157);
- Flexion-adduction-external rotation with knee flexio (Beckers & Buck, 2021, p. 159);
- Flexion-adduction-external rotation with knee extension (Beckers & Buck, 2021, p. 161);
- Extension-abduction-internal rotation (Beckers & Buck, 2021, p. 162);
- Extension-abduction-internal rotation with knee extension (Beckers & Buck, 2021, p. 165)
- Extension-abduction-internal rotation with knee flexion (Beckers & Buck, 2021, p. 166).

8.2. Medical rehabilitation in order to facilitate ambulation - the experimental group, using the horizontal pedal device for the motor rehabilitation of the lower limbs

8.2.1. Stationary horizontal pedal device

The stationary horizontal pedal device described in Chapter 7, 7.1-7.4 ensures:

- minimizing the effects of inactivity and immobility (improving side effects of inflammation, reducing/improving pain);
- cardiovascular resistance;
- neuromuscular coordination - strengthening the balance position of subjects in long sitting (supine with partial weight unloading, with the lower limbs in triple flexion, in different degrees of amplitude);
- addressing neuro-motor deficiencies;
- improving the range of motion, muscle function deficits and remaining ones by changing the distance to the pedals and setting different intensities;
- promoting the return to functional activity;
- reducing the risks of associated comorbidities, remedying or preventing deficiencies, optimizing general health and well-being.

The benefits of exercises that involve large muscle groups are the improvement of aerobic capacity, the reversal of muscle atrophy, the increase of muscle functionality, the increase of muscle strength. The application of exercises in the controlled open/closed kinetic chain is aimed at restoring/maintaining muscle power, correcting movement patterns and muscle imbalances, regaining strength and endurance, improving cardiovascular and respiratory capacity, creating a fast and efficient rehabilitation program.

Controlled open/closed kinetic chain exercises have neurophysiological effects that stimulate the proprioceptive system via feedback to initiate and control muscle activation patterns.

8.2.2 Medical rehabilitation protocol

The experimental group also includes five subjects with the indication of physiotherapy from the specialist doctor: a patient with damage to the coxo-femoral joint (right coxarthrosis associated with lumbosciatica), a patient with stroke and left hemiparesis, a patient with damage to the knee joint (gonarthrosis and associated comorbidities) and two patients with damage to the ankle joint (post-sprain, respectively post-fracture status). All patients had a history of an episode of COVID-19. The recovery program lasted 4 weeks with a frequency of 3 times a week, in total 12 sessions (min 50 min/session).

The goals of pedaling exercise therapy are as follows**:**

a) Promoting activity and minimizing the effects of inactivity, increasing independence;
b) Increasing the normal/functional range of motion;
c) Improving the strength of weak muscles;
d) Improving performance in daily activities;
e) Facilitation of ambulation;
f) Reduction of muscle, tendon and fascia contracture, reduction of stiffness;
g) Improvement of circulation and respiratory capacity;
h) Improving coordination and balance;
i) Promotion of relaxation;
j) Increase in motor or sensory function;
k) Reduction of medication, reduction of hospital visits and increase of general health.

Patient management is based on the three-dimensional intervention model of therapeutic exercise that takes into account the elements of the movement system, the specificity of the activity and the particular dosage of its intensity, according to **Table 8.2**..

Table 8.2 The three-dimensional intervention model of the therapeutic exercise

The elements of the movement system - the purpose of each activity and the technique	The specifics of the chosen activity/technique	Specific dosage
Support – reinforced balance reaction	Posture - supine - long sitting	Eccentric/concentric type of contraction; isometry; resistive contractions
Base – static horizontal pedaling	Mode – active, rhythmic rotation	Intensity depending on riskogram/ IMF/pathology
Modulator – 5 levels of intensity	Movement – closed-open controlled kinetic chain	Intensity depending on riskogram/IMF/ pathology
Biomechanics – assessment of joint and muscle balance, muscle imbalances		Duration depending on riskogram/ IMF/SMI/ pathology
Cognitive/affective impact – specialist evaluation		Frequency according to riskogram/ IMF pathology
		Sequence - intervention phase (I-II-III))
		Feedback (monitoring perceived effort, heart rate)

FMI = adipose tissue index; SMI= muscle tissue index, calculated by reporting to the square of the height of the results obtained by bioimpedance measurements, part of the patient's riskogram (Hattori et al., 1997; Keller & Engelhardt, 2013).

In performing the exercises, static and dynamic biomechanics have a primary role in which the cardiopulmonary and metabolic support, the musculoskeletal base and the nervous system as a modulator intervene.

The therapeutic exercises used as inducers to promote engramming are based on adaptation and must take into account the modifying factors and necessary corrections.

8.2.3 Physiotherapy program adapted to the experimental group.

The therapeutic exercise with the help of the stationary horizontal bicycle respects the characteristics expressed in **Table 7.8**, to which are added the work observations depending on the pathologies of the patients included in the experimental group - **Table 8.3**.

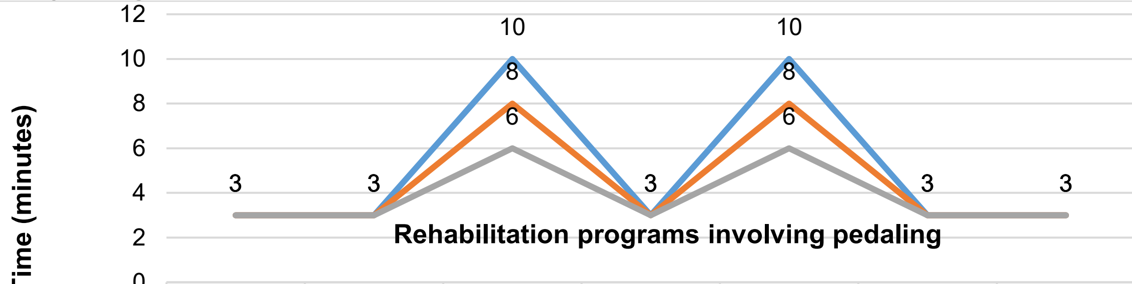
Table 8.3 Work observations according to the pathologies of the patients included in the experimental group

Work observations	Details - pedaling
Initial starting position	The movement is initiated from at least 10 degrees knee flexion without resistance, pedaling with the leg outstretched with support on the heels.
Submaximal effort	Submaximal effort is recommended - defined as one minute before reaching the anaerobic threshold; the individual anaerobic threshold was identified at about 75% of the maximum heart rate or Borg scale = 4/10.
Rehabilitation of knee conditions	It starts from flexion 50-90 degrees, the target being 110 degrees. The stationary bike is used to encourage full extension of the knee as it progresses, especially in patients with osteoarthritis. The rehabilitation of the pelvic girdle musculature controls the function of the knees proximally. Post-traumatic osteoarthritis is characterized by chronically unstable knees. Pedaling corrects mechanics, increasing strength, flexibility, endurance and motor control.
Recovery of hip conditions	An angle of 90o in flexion of the knee must not be exceeded in order not to overload the coxo-femoral joint area for patients with pathologies associated with it. It is possible to evaluate at which degree of flexion the pain appears, at least in the first stage of recovery, and it is determined from which degree of flexion to start pedaling in order not to reach maximum flexion in the painful area. Pedaling involves functional strengthening, training of posture and body mechanics: external rotation of the eccentric hip leads to internal rotation of the femur to support the knee, the indirect effect being tibial rotation and subtalar pronation.
Full functional range of motion	Mobility of the quadriceps-hamstring force couple
Increasing the resistance and strength of the thigh and knee muscles	The total extension of the knee favors increasing the resistance and strength of the thigh and knee muscles by moving the patient away from the pedals, and the approach favors increasing the articular amplitude of the knee. Toning begins when the pain subsides. The rehabilitation program for correcting the deficit of strength, endurance and flexibility of the muscles must also include the pelvic girdle.

Stability, balance, proprioception, neuromuscular control	For stability, balance, proprioception, neuromuscular control, a minimum of 4 weeks of rehabilitation is practiced
Pedaling	Pedaling reduces the risk of re-injury after tearing the lateral ankle ligament. Pedaling for 30 minutes with low aerobic intensity favors lymphatic drainage.

Therapeutic program using the horizontal stationary bicycle included in the protocol of the experimental group

The types of pedaling programs proposed are based on the risk profile of the patients determined according to the body composition of each patient, the associated comorbidities and the indications of specialist doctors: program A – high risk (27 min.), Program B – medium risk (31 min.) , Program C – minimum risk (35 min.), with an interspersed 9-minute break, according to **Figure 8.1**.



Program Type	Initial basic rhythm (warm up)	Pause	Fast pedaling	Pause	Easy pedaling	Pause	Final basic rhythm (cool down)
A Program	3	3	10	3	10	3	3
B Program	3	3	8	3	8	3	3
C Program	3	3	6	3	6	3	3

Figure 8.1 Rehabilitation programs involving pedaling

The division of patients will be done according to pathologies to determine **the duration** and **specificity** of each series of therapeutic exercises, 50 minutes/session – **Table 8.4.**

The background condition of the patients is taken into account to determine the rhythm, intensity, pedaling frequency, cardio-pulmonary capacity, degree of perception of the effort and the load of the patient depending on the chosen intensity. Through bio-impedance, the patient's somatotype was established according to muscle indices, fat tissue and non-fat tissue and the appropriate dosage of therapeutic exercises, according to the riskogram of each patient (Murgoci, Mereuță, et al., 2022)

Table 8.4 The detailed content of the physical therapy program adapted to the experimental group

Content of the proposed physical therapy program adapted to each condition (minutes)	**Coxarthrosis, lombosciatica (mechanical origin) 1 subject**	**Gonarthrosis, lumbosciatica (mechanical origin) 1 subject**	**Ischemic stroke hemiparesis 1 subject**	**Post-trauma lower limbs 1 subject**	**Post-trauma lower limbs 1 subject**
Therapeutic massage	5	5	5		
Manual lymphatic drainage				8	4
Invessie table positioning	4	5			
Static horizontal pedaling - adapted programs A/B/C	31	35	31	27	31
Postural treatment - Positions at the edge of the bed in short sitting *			4		
FNP – Kabat- active				5	5
Manual therapy, stretching	10	5	10	10	10
Total time (minutes) of which	**50**	**50**	**50**	**50**	**50**
active	**22**	**26**	**22**	**23**	**27**
passive	**19**	**15**	**15**	**18**	**14**
***active break**			**4**		
passive pause	**9**	**9**	**9**	**9**	**9**

CHAPTER 9. PRESENTATION, ANALYSIS AND INTERPRETATION OF THE RESULTS OF THE PRELIMINARY EXPERIMENTAL RESEARCH

9.1. Presentation of the subjects and the results of the evaluations of the control group and the experimental group

9.1.1. Presentation of the subjects and their specific demographic characteristics

The control group and the experimental group included five subjects each, and to preserve the homogeneity of the study, 10 patients with similar basic impairment were selected from 27 patients to respect the principle of data comparability - **Table 9.1**.

Each group contains one patient with coxo-femoral joint damage, one patient with stroke, one patient with knee joint damage and two patients with ankle joint damage. All patients included in the study had a mild to moderate episode of COVID-19 that did not require hospitalization or oxygen therapy.

The rehabilitation program lasted 4 weeks with a frequency of 3 times a week, in total 12 sessions (50 min/session).

Table 9.1 Presentation of the subjects included in the preliminary experimental research

No	Subjects	Main diagnosis + Comorbidities	Pacient Type	Age	Gender	IMC	Interpretation IMC
1	C.N.	Right coxarthrosis, Lumbosciatica, Status post Covid-19	C	45	M	27.93	Overweight
2	B.I.	Left ankle post-sprain status, post-Covid-19 status	C	78	M	24.10	Normal
3	G.L.	Ischemic stroke with left hemiplegia, HTAE stage 3, Status post-Covid-19	C	53	F	21.57	Normal
4	O.P.	Gonathrosis, Dyslipidemia, HTAE stage 3, Status post-Covid-19	C	74	M	36.88	Obesity
5	G.V.	Reduced open postfracture left tibia and fibula status with osteosynthesis	C	49	F	30.60	Obesity
6	P.E.	Left ankle post-fracture status, post-Covid-19 status	E	44	F	22.03	Normal
7	A.J.	Right coxarthrosis, L4-L5 disc herniation stage 2, Status post-Covid-19	E	43	M	32.57	Obesity
8	I.A.	Gonarthrosis, Rheumatoid arthritis, Coxarthrosis, HTAE stage 2, Hypothyroidism, Dyslipidemia, Post-Covid-19 status	E	73	F	28.32	Overweight
9	D.E.	Ischemic stroke, left hemiparesis, HTAE stage 3, Status post-Covid-19	E	52	M	27.80	Overweight
10	S.C.	Status post-luxatie glezna dreaptă, Status post Covid-19	E	76	F	25.40	Overweight

C=control, E = experiment, IMC = body mass index, AVC = stroke, HTAE = essential hypertension

The presentation of the subjects included, in addition to the main diagnosis and associated comorbidities, the type of patient coded with C or E depending on the control group or the experimental group, age, gender and interpretation of the body mass index.

9.1.2. Evaluation of pain before and after the application of physiotherapy programs at the level of the control group and the experimental group

The interpretation of the results of the visual analog scale of pain by numerical association respected the following standardization: 0- no pain, 1-3 mild pain, 4-7 moderate pain, 8-10 severe pain. The moment T0 was considered the one before the start of the rehabilitation therapy and the moment T1 after four weeks of applying the rehabilitation program related to the control group, respectively the experimental group, according to **Tables 9.2** and **9.3**.

Table 9.2 Pain assessment (visual analogue scale VAS 0/10) - control group

No	Subjects	VAS T0	VAS T1
1	C.N.	6	3

2	B.I.	5	4
3	G.L.	4	1
4	O.P.	6	4
5	G.V.	7	5

Table 9.3 Pain assessment (visual analogue scale VAS 0/10) – experimental group

Nr. crt.	Subiecţi	VAS T0	VAS T1
1	P.E.	6	3
2	A.J.	7	3
3	I.A.	5	3
4	D.E.	4	0
5	S.C.	5	1

9.1.3 Joint balance - goniometry before and after the application of the physiotherapy programs at the level of the control group and the experimental group

The articular balance (BA) performed by goniometry before and after the application of the physiotherapy programs at the level of the control group and the experimental group concerned the coxo-femoral joint (CF), the knee joint (G) and the ankle joint (GZ) related to the left affected limb or right depending on the pathology. Flexion was evaluated for the hip and knee joint and both flexion and extension for the ankle. Gained range of motion was assessed separately as the difference between time T1 and time T0. For each patient, the most affected joint(s) was marked according to **Table 9.4**.

Table 9.4 Joint balance – goniometry (values expressed in degrees)

Subiecţi	tip	BA CF T0	BA G T0	BA GZ F T0	BA GZ E T0	BA CF T1	BA G T1	BA GZ F T1	BA GZ E T1	BA CF (T1-T0)	BA G (T1-T0)	BA GZ F (T1-T0)	BA GZ E (T1-T0)
1.C.N.	C	60	100	15	35	75	120	19	45	15	20	4	10
2.B.I.	C	85	120	5	34	90	130	11	40	5	10	6	6
3.G.L.	C	40	80	3	27	60	100	7	32	20	20	4	5
4.O.P.	C	75	75	10	43	85	90	15	49	10	15	5	6
5.G.V.	C	75	90	8	38	90	110	16	44	15	20	8	6
6.P.E.	E	90	110	6	23	90	120	13	43	0	10	7	20
7.A.J.	E	55	95	12	32	78	125	17	42	23	30	5	10
8.I.A.	E	45	55	5	28	55	70	10	36	10	15	5	8
9.D.E.	E	35	75	3	29	60	92	8	42	25	17	5	13
10.S.C.	E	80	115	4	31	90	125	11	46	10	10	7	15

C = patient from the control group, E = patient in the experimental group, T0 = initial, T1 = after 4 weeks (3 times/week, 12 sessions), BA = joint balance - affected side (left/right) coxo-femoral joints (CF), knee (G), ankle (Gz)

9.1.4. Muscle balance before (T0) and after (T1) the application of physical therapy programs at the level of the control group and the experimental group and the highlighting of muscle imbalances between the left and right lower limb

The muscle balance tests a relative maximum force at a given time with the manual muscle testing method - the MRC Medical Research Council scale with 6 levels (0-5) for each muscle group of the lower limb as follows thigh flexion, knee extension, leg dorsiflexion (ankle and fingers), before (BM T0) and after (BM T1) the application of physiotherapy sessions. The most affected muscle group was recorded according to the pathology of each patient.

Muscular imbalances, evaluated with the static horizontal pedal system expressed in similar average values for the right and left lower limb and the highlighting of the differences between them before (Dif VAM T0) and after (Dif VAM T1) the application of the physiotherapy sessions were reproduced in **Table 9.5**.

For the control group, a 3-minute pedaling with a controlled moderate effort was performed for evaluation purposes only, unlike the experimental group where pedaling had both a therapeutic and evaluation role.

Table 9.5 Muscle balance and the highlighting of muscle imbalances - Dif VAM

Subjects	Type	Dif VAM T0	Dif VAM T1	BM T0	BM T1	BM (T1-T0)
1.C.N.	C	32	20	4	5	1
2.B.I.	C	26	10	4	5	1
3.G.L.	C	84	55	2	3	1
4.O.P.	C	42	25	3	4	1
5.G.V.	C	56	32	3	4	1
6.P.E.	E	39	12	3	5	2
7.A.J.	E	43	18	4	5	1
8.I.A.	E	30	8	3	4	1
9.D.E.	E	107	75	2	3	1
10.S.C.	E	29	9	4	5	1

VAM = average analog value, BM - muscle balance - MRC units, C-control, E – experiment

9.1.5 Monitoring values of perceived effort (BORG scale) and heart rate during the application of physiotherapy programs at the level of the control group and the experimental group

Heart rate reserve as well as recovery training heart rate calculated according to Karvonen's formula: Target heart rate (FC) = [(Maximum FC - Resting FC) × % Intensity] + Resting FC (Tudor Sbenghe, 2002, p. 569).
A gradual intensity of 40-60% was proposed, in this way not exceeding the lactate threshold.
Heart rate monitoring was carried out with the Huawei Watch GT 2 Smartwatch according to **Table 9.6**, taking into account the phases of rehabilitation – 12 sessions in total, distributed 4 for each of the 3 levels of intensity of the recovery treatment
The maximum heart rate was set as the interval between an upper limit determined as FCM1 = maximum heart rate 1 = (220-age) **and a lower limit** determined as FCM2 = maximum heart rate (215- age *0.66), for each limit calculating target heart rate.

Table 9.6 Heart rate monitoring values

Rehabilitation Phases						Phase I.1	Phase I.2	Phase II.1	Phase II.2	Phase III.1	Phase III.2	Phase 1	Phase 2	Phase 3
Subjects	Type	Age	FCR	FCM1	FCM2	FCT1 (I=40%)	FCT2 (I=40%)	FCT1 (I=50%)	FCT2 (I=50%)	FCT1 (I=60%)	FCT1 (I=60%)	FC1	FC2	FC3
1.C.N.	C	45	75	175	185	115	119	125	130	135	141	118	129	139
2.B.I.	C	78	80	142	164	102	110	109	122	117	130	105	111	126
3.G.L.	C	53	77	167	180	112	117	121	129	131	139	115	127	138
4.O.P.	C	74	90	146	166	103	111	111	128	124	136	110	126	134
5.G.V.	C	49	67	171	183	113	118	123	125	129	136	116	124	138
6.P.E.	E	44	80	176	186	115	119	126	133	138	144	116	127	140
7.A.J.	E	43	75	177	187	116	120	126	131	136	142	118	129	141
8.I.A.	E	73	65	147	167	104	112	111	116	114	126	106	113	117
9.D.E.	E	52	70	168	181	112	117	122	125	129	136	114	123	130
10.S.C.	E	76	85	144	165	103	111	110	125	120	133	105	111	121

FCR= resting heart rate, FCM1 = maximum heart rate (220-age), FCM2 = maximum heart rate (215-age*0.66); C = control; E = experiment
FCT1= Target heart rate 1= [(Maximum FC 1 – Resting FC) ×40% Intensity] + Resting FC) related to the phase 1 (I=40%), 2 (I=50%), 3 (I=60%)
FCT2= Target heart rate 2 = [(Maximum FC 2 - Resting FC) ×40% Intensity] + Resting FC) related to the phase 1 (I=40%), 2 (I=50%), 3 (I=60%)
I = Effort Intensity (40%, 50%; 60%); FC 1, 2, 3 = heart rates measured according to the rehabilitation phase

The Borg scale, graded from 1 to 10, reveals the perception of pedaling effort and was used to establish the initial basic rhythm that corresponds to an intensity level agreed by the patient, the conditioning being aerobic. For recovery, the level of perceived effort must not exceed the moderate level: Borg = 4-6, in order not to reach the lactate threshold (Borg, 1982). In postacute rehabilitation, a maximum score on the Borg scale of 4/10 for dyspnea and fatigue is recommended according to the post-Covid rehabilitation protocol (EMITENT MINISTERUL SĂNĂTĂȚII, 2021). I note that each patient had at least one mild-to-moderate COVID-19 episode that did not require hospitalization or oxygen therapy, with eight patients being vaccinated and two patients not being vaccinated.

Table 9.7 Perceived effort monitoring values (BORG scale)

No.	Subjects	Type	BORG
1	C.N.	C	4
2	B.I.	C	3
3	G.L.	C	4
4	O.P.	C	3
5	G.V.	C	4
6	P.E.	E	4
7	A.J.	E	4
8	I.A.	E	3
9	D.E.	E	4
10	S.C.	E	3

The perceived effort was evaluated for the control group and the experimental group after performing the standard and the proposed physiotherapy program (**Table 9.7**) during the 12 sessions held over 4 weeks.

9.1.6. Values resulting from the bioimpedance analysis of the subjects

Body composition measurements obtained by bioimpedance used the Amazfit Smart Scale - Body Composition Analyzer (Declaration of Conformity with directives 2014/53/EU and 2014/65/EU) from the practice's own endowment, using a single frequency of 50 kHz. For each subject, major body compartments determined as tissue systems were determined, automatically estimated by linear empirical equations stored in the system memory along with personal physical data (age, weight, height).

• Exclusion criteria related to bio-impedance measurements included all situations of alteration of the hydro-electrolyte balance (hepatic, renal, decompensated heart diseases), acute-contagious infections, subjects wearing pacemakers, people with skin lesions and pregnant women.
• Inclusion criteria related to bio-impedance measurements targeted any patient with a medical indication for physical therapy from the specialist doctor; restrict the consumption of food and liquids for at least 4 hours and alcohol for at least 8 hours before the test.
• Procedure: subjects in orthostatism with bare feet in contact with the conductive surface.

Table 9.8 Values resulting from the bioimpedance analysis of the subjects

Subjects	Type	FM (Kg)	SM (Kg)	FFM (Kg)	Water(l)	Protein (Kg)	Bone Tissue (Kg)
1.C.N.	C	26.22	34.70	59.76	45.11	11.46	3.20
2.B.I.	C	16.72	27.30	50.13	36.29	11.14	2.70
3.G.L.	C	15.45	19.90	36.25	27.36	6.89	2.00
4.O.P.	C	40.08	35.10	60.45	45.60	11.56	3.30
5.G.V.	C	33.76	22.50	40.49	30.47	7.43	2.60
6.P.E.	E	17.78	21.80	39.19	29.57	7.23	2.40
7.A.J.	E	33.92	36.20	62.15	46.98	11.77	3.40
8.I.A.	E	30.23	22.30	39.91	30.16	7.25	2.50
9.D.E.	E	24.10	31.70	54.90	41.45	10.45	3.00
10.S.C.	E	24.99	19.20	34.92	26.41	6.51	2.00

FM = adipose tissue, SM = skeletal muscles, FFM = Non-adipose tissue;

The values resulting from the bio-impedance analysis of body composition highlighted adipose tissue (FM), skeletal muscles (SM), non-adipose tissue (FFM), the amount of protein and bone tissue, expressed in kilograms and the amount of water expressed in liters for all patients included in the study according to **Table 9.8**.

Following the statistical analysis of these indicators, a risk profile was established for each subject, followed by an individualized dosage of the therapeutic exercise.

CHAPTER 10 CONCLUSIONS PART II

The conclusions, which were grouped according to the measured parameters and statistical interpretations, were presented in the published study on the comparative study of the effectiveness of motor rehabilitation of the lower limbs using a static horizontal bicycle *versus* standard rehabilitation programs (Murgoci, 2022a).

10.1. General characteristics

1. The control group and the experimental group each included five subjects with the following general characteristics**:**

- Relatively homogeneous age groups in both the control group and the experimental group: age group 40-49 years - 40% (two subjects), age group 50-69 years - 20% (one subject) and age group >70 years - 40% (two subjects) – **Figure 10.1**;

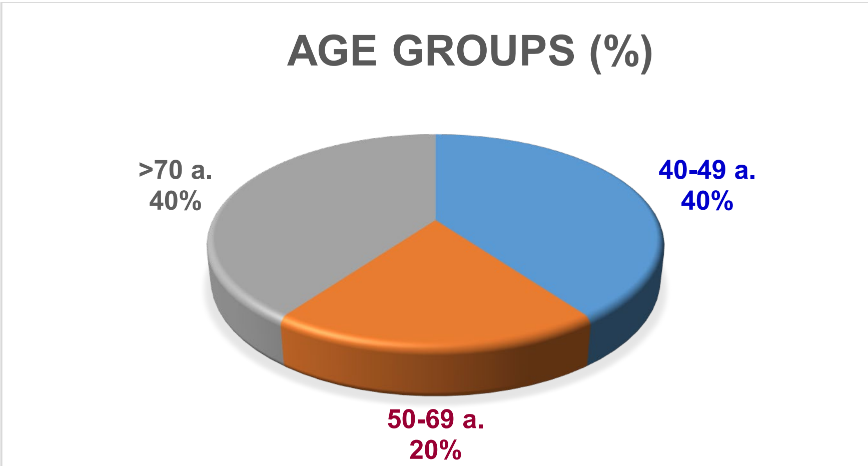
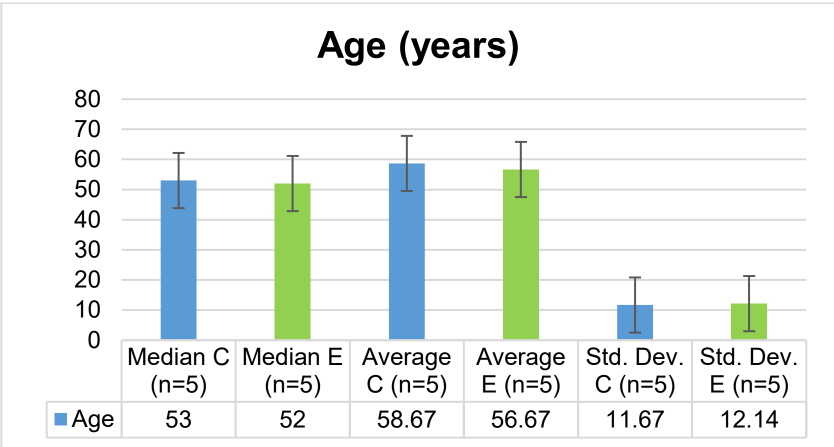


Figure 10.1 Age groups (%)

The control group had a mean age of 58.67±11.67 years, a mean of 53 years compared to the mean age of the experimental group of 56.67±12.14 years, a mean of 52 years – **Figure 10.2.**



	Median C (n=5)	Median E (n=5)	Average C (n=5)	Average E (n=5)	Std. Dev. C (n=5)	Std. Dev. E (n=5)
Age	53	52	58.67	56.67	11.67	12.14

Figure 10.2 Age (years) - comparison between control (C) and experimental (E) group

- The control group according to gender includes two women -40% (one subject belonging to the group 40-49 years old and one subject belonging to the group 50-69 years old) and three men - 60% (one subject belonging to the group 40-49 years old and two subjects >70 years)– **Figure 10.3**;

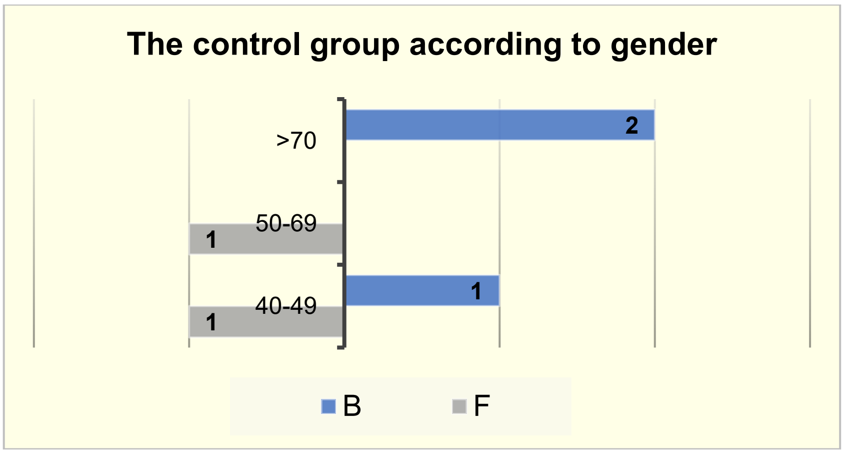


Figure 10.3 The control group according to gender (B- men, F-women**)**

- The experimental group according to gender includes 3 women - 60% (one subject belonging to the 40-49 years old group and two subjects >70 years old) and 2 men - 40% (one subject belonging to the 40-49 years old group and one subject belonging to the group 50-69 years)- **Figure 10.4**;

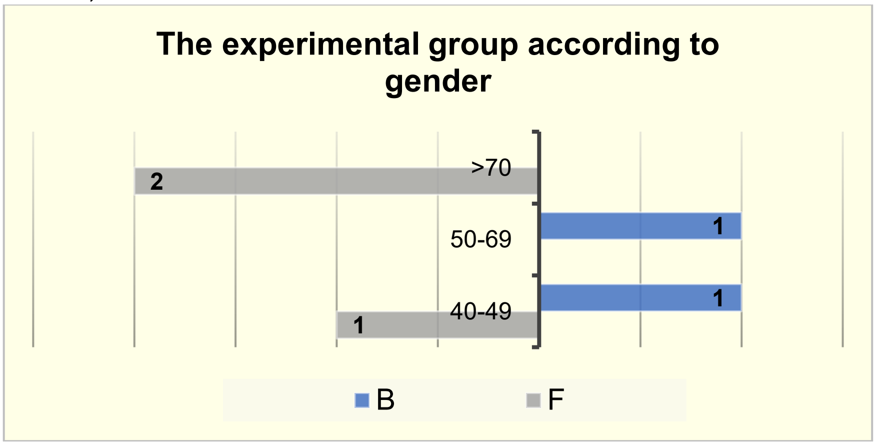


Figure 10.4 The experimental group according to gender (B- men, F-women**)**

- IMC (BMI) of the control group: 40% of the subjects have normal weight (one subject belonging to the 50-69 years group and one subject >70 years), 20% are overweight (one subject belonging to the 40-49 years group) and 40% obese (one subject belonging to the 40-49 years group and one subject >70 years) – **Figure 10.5**;

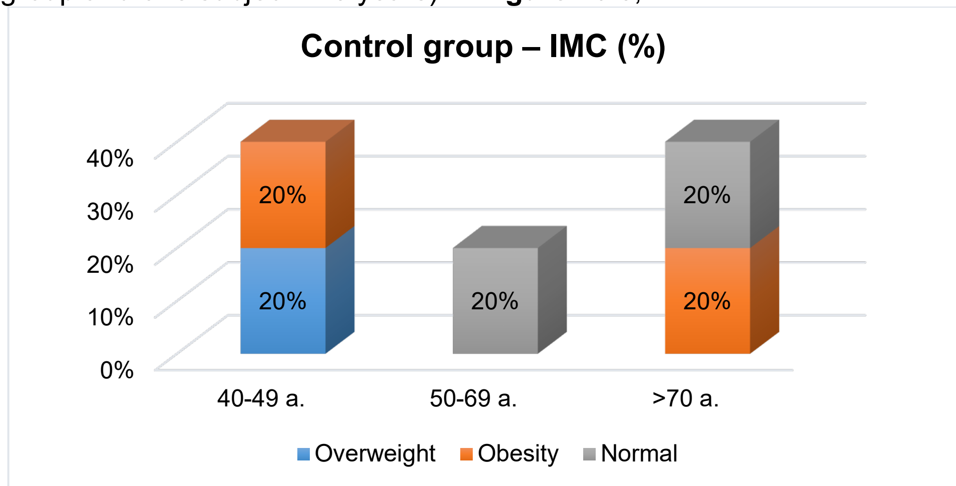


Figure 10.5 Control group – IMC (%)

- IMC (BMI) of the experimental group: 20% of the subjects have normal weight (one subject belonging to the 40-49 years old group), 60% are overweight (one subject belonging to the 50-69 years old group and two subjects >70 years old) and 20% obese (a subject related to the 40-49 age group) – **Figure 10.6**.

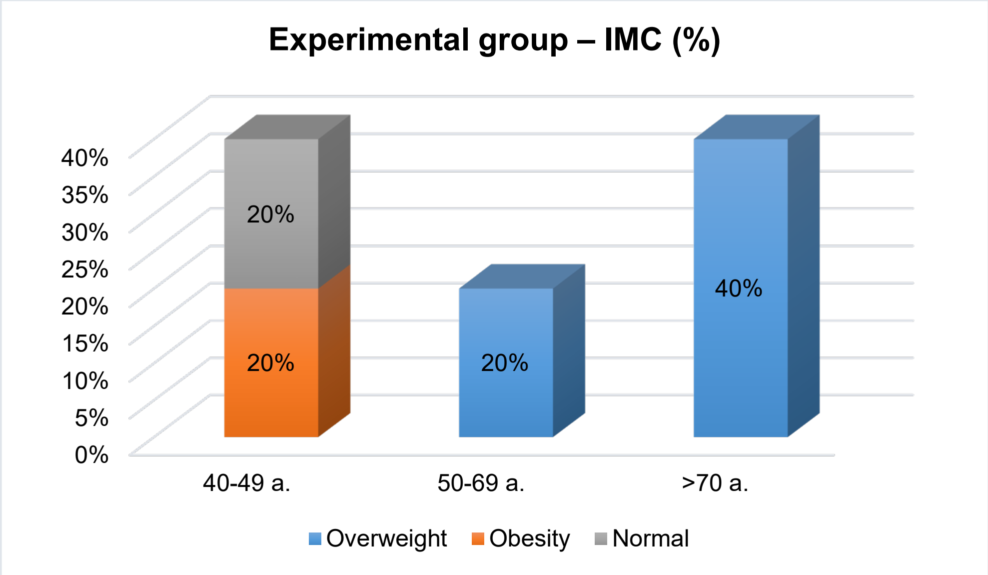
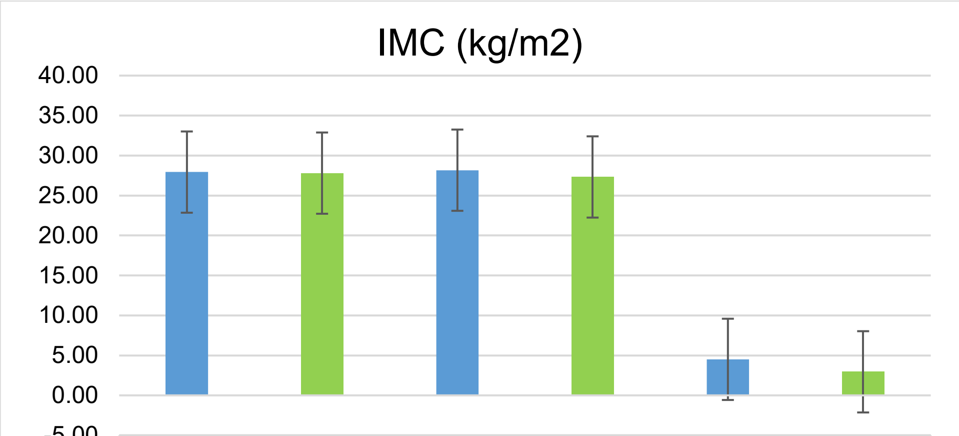


Figura 10.6 Experimental group – IMC (%)

- IMC (kg/m2) - BMI (kg/m2) for the control group recorded a mean of 28.17±4.50, a median of 27.93 compared to the mean of the experimental group of 27.32±2.94, a mean of 27.80– **Figure 10.7**.



	Median C (n=5)	Median E (n=5)	Average C (n=5)	Average E (n=5)	Std. Dev. C (n=5)	Std. Dev. E (n=5)
IMC	27.93	27.80	28.17	27.32	4.50	2.94

Figure 10.7 IMC (Kg/m2) – comparison between control and experimental group

2. The Spearman correlations at the level of the control group and the experimental group highlighted:

- at the level of the control group, a strong negative association between the male gender and the Adipose FMI somatotype, as well as with the Intermediate FFMI somatotype and a strong positive association between the Adipose FMI somatotype and the Intermediate FFMI (p<0.001, CI = 99%).

- at the level of the experimental group, they highlighted a strong positive association between the Adipose somatotype (FMI) and the Overweight IMC (p<0.001, CI = 99%).

3. The T-test applied to the analyzed somatotypes were statistically relevant for both groups. The ANOVA according to the FMI somatotype (dependent variable) in the control group and the experimental group showed a p= 0.029, the effect size = 0.515, that is, in 51.5% of the total subjects, the weight of adipose tissue significantly influences the IMC (BMI) value. **In the experimental group, pedaling program A** (27 minutes) – one subject, **B** (31 minutes) – three subjects and **C** (35 minutes) was applied to one subject, in correlation with the somatotype of each patient and the associated risk.

4. Sarcopenia was not identified in the patients from the preliminary experimental research based on bio-impedance depending on the age groups and gender, instead the adipose somatype represents an important risk factor for all the analyzed age groups.

10.2. Pain assessment

1. The parametric test z (t) for the mean of the control group, respectively of the experimental group

- The conclusion of the z (t) test applied to the control group (N=5) shows that the average of the research sample differs significantly from the average of the standard population (average = 5.60, std.dev. = 1.140, standard error of the average = 0.510), the results of the statistical test being expressed by t=10.983, df = 4, p=0.000, statistically relevant result.
- The conclusion of the z (t) test applied to the experimental group (N=5) shows that the average of the research sample differs significantly from the average of the standard population (average of 5.40, std.dev. = 1.140, standard error of the average=0.510), the test results statistically being expressed by t=10.590, df =4, p=0.000, statistically relevant result – **Figure 10.8**.

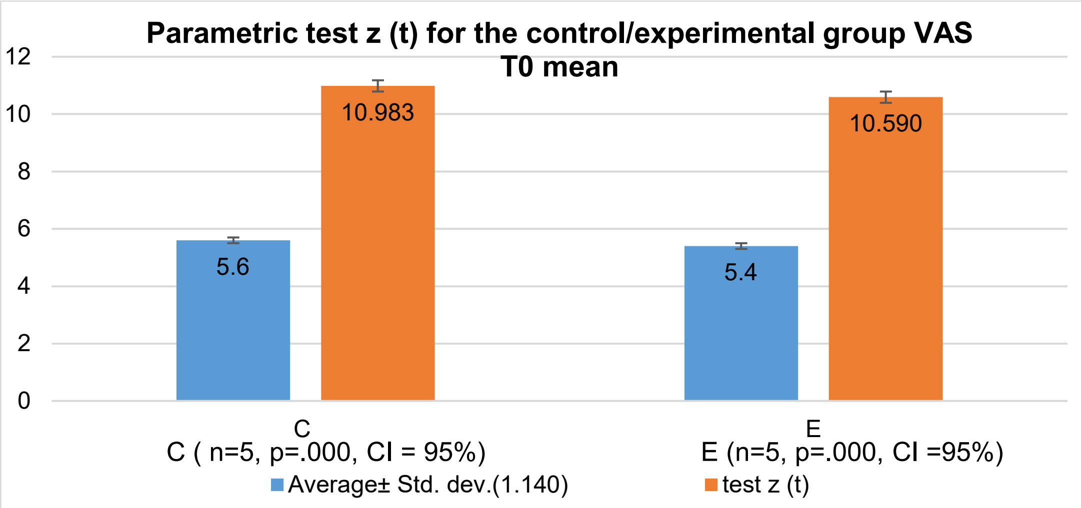


Figure 10.8 Parametric test z (t) for the control/experimental group mean

2. The T-test for paired samples allows the evaluation of the significance of the variation of the VAS, in the same subjects, in two different situations: before and after the rehabilitation program.

- Statistically, the standard rehabilitation program had relevance, the observed difference between the VAS averages before and after the rehabilitation program is 2.2, the T-test value is 5.880 for the p < .004 threshold, so there is an effect of the standard rehabilitation program on the control group;
- Statistically, the proposed experimental rehabilitation program was relevant, the observed difference between the VAS averages before and after the rehabilitation program is 3.4, the value of the T test is 8.550 for the p < .001 threshold, so there is an effect of the experimental rehabilitation program on the experimental;

Comparatively, the threshold of p < .001 for the experimental group has a higher relevance than the threshold of p < .004 for the control group – **Figure 10.9**

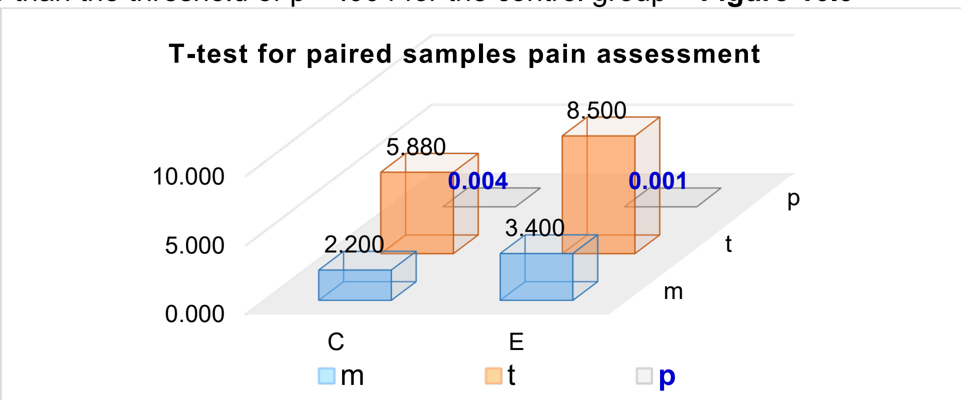


Figure 10.9 T-test for paired samples

3. The sign test or the Z test or the Wilcoxon test, used to test the differences between the values showed a greater significance for the experimental group 0.039 versus 0.041 the control group related to the VAS (p<0.05)– **Figure 10.10.**

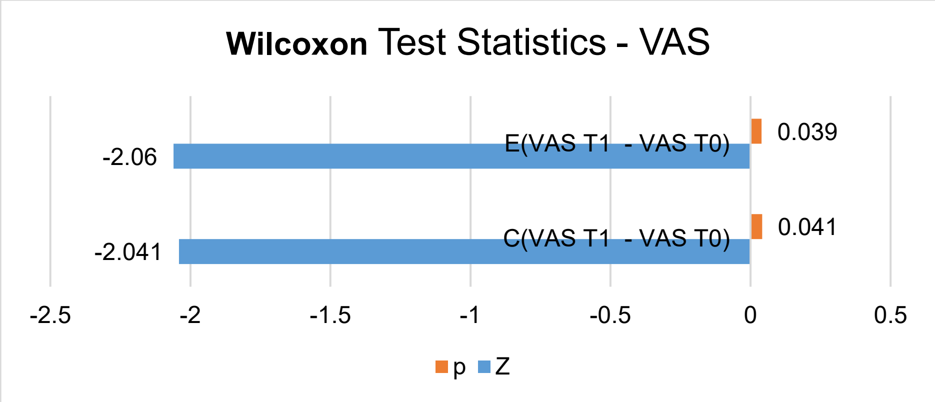


Figure 10.10 Wilcoxon test for paired samples

10.3 Joint Testing

1. The Wilcoxon test for two paired samples reveals statistical significance for both programs, each applied to groups of independent patients (p=0.042 for the control group, respectively p=0.043 for the experimental group)- **Figure 10.11.**

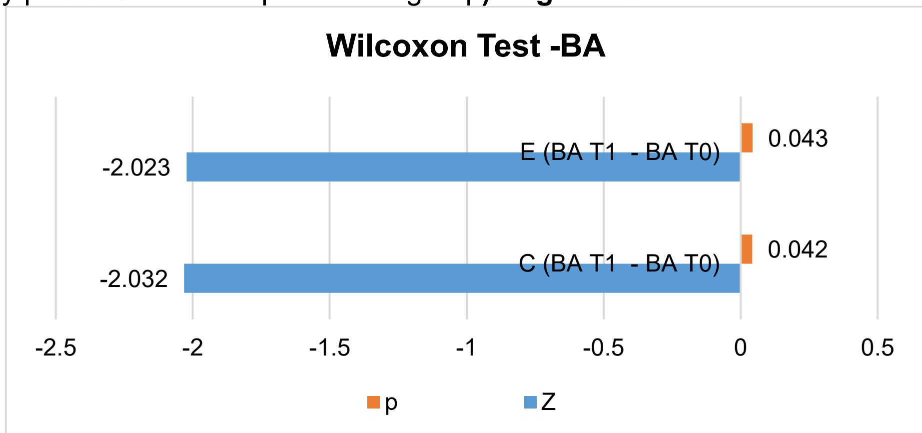


Figure 10.11 Wilcoxon test for two paired groups

2. T-test for independent paired groups

The result of the t-test highlights the confirmation of the research hypothesis, namely the fact that the proposed physical therapy program is more effective than the standard one at T0 (mE = 41.20 vs. mC = 50) and T1 (mE = 62.20 vs. mC = 63). Due to the variability of measurements at the level of three different joints and various pathologies, the T-test for paired samples is not conclusive.

3. T-test for dependent paired samples

- There is an effect of the standard rehabilitation program on the improvement of the joint balance values of the control group, the observed difference between the means is -13, the T test value is -11.402 for the p < .000 threshold.

- There is an effect of the proposed rehabilitation program on the improvement of the articular balance values of the experimental group, the observed difference between the means is -21, the T test value is -10.127 for the p < .001 threshold – **Figure 10.12**.

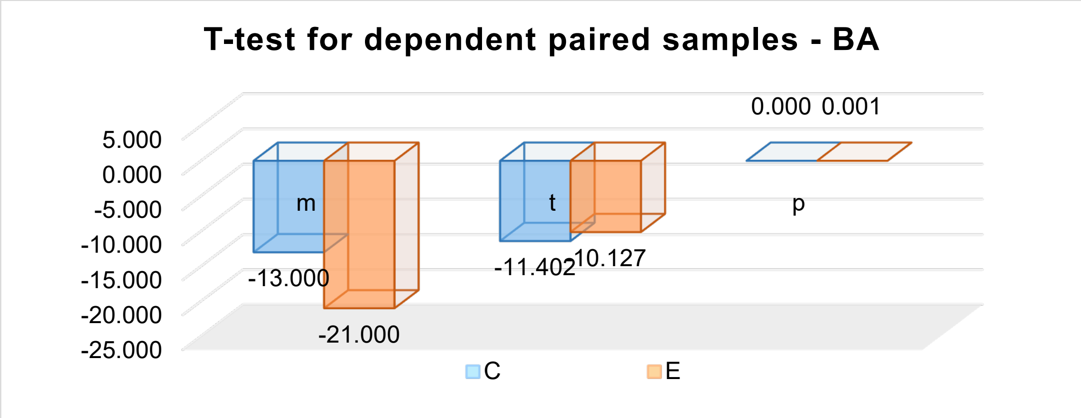


Figure 10.12 T-test for dependent paired samples

10.4. Muscle balance

1. Analysis of muscle imbalances with control bars – analog values transmitted by sensors reveals:

- in the control group an average of 48 average analogue values in absolute value, which was reduced to 28.4 average analogue values after the standard physiotherapy program, the difference being 19.6 units.

- in the experimental group, an average of 49.6 average analog values in absolute value, which was reduced to 24.4 average analog values in absolute value after the proposed physical therapy program, the difference being 25.2 units.

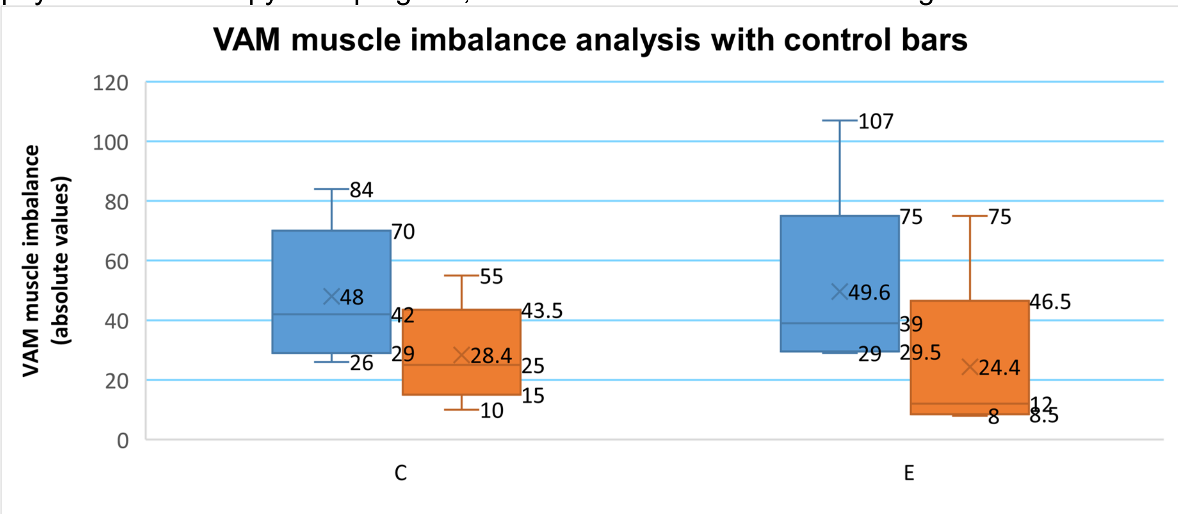


Figure 10.13 VAM muscle imbalance analysis with control bars

Therefore, there was a 28.5% [(25.2-19.6)/19.6]* 100 reduction of muscle imbalances associated with the lower limbs with the proposed physical therapy program compared to the standard program, so the proposed rehabilitation program with the static horizontal pedal board was more efficient with 28.5% compared to standard therapy – **Figure 10.13**.

2. The analysis of muscle balance in MRC units reveals:

- in the control group an average of 3.2 MRC, which improved to 4.2 MRC after the standard physiotherapy program, the difference being 1 MRC unit.

- in the experimental group, an average of 3.2 MRC, which improved to 4.4 MRC after the proposed physical therapy program, the difference being 1.2 units.

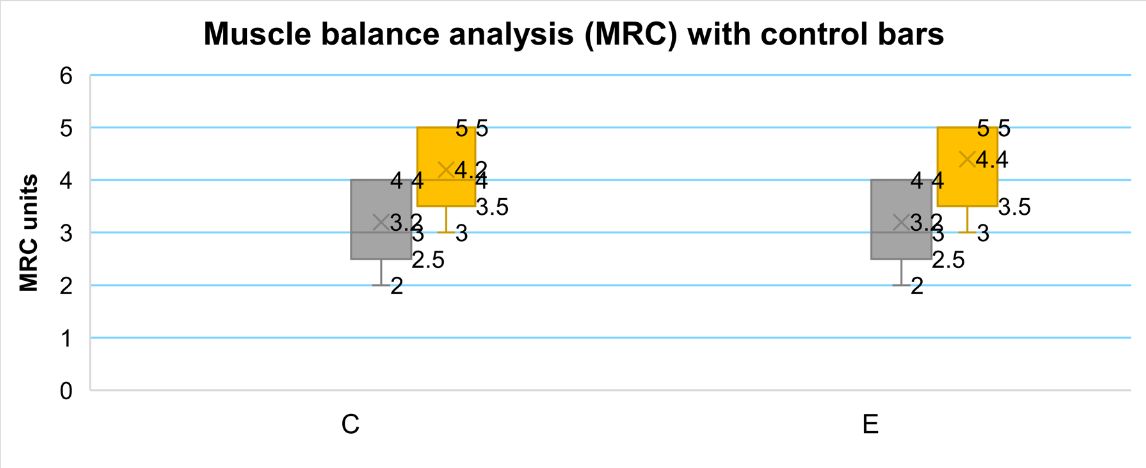


Figure 10.14 Muscle balance analysis (MRC) with control bars

Therefore, there was a 20% [(1.2-1)/1]* 100 improvement in muscle imbalances associated with the lower limbs with the proposed physical therapy program compared to the standard program – **Figure 10.14**.

3. Paired-samples T-test applied to muscle imbalances expressed as the difference in mean analog values between the intact and the affected lower limb

- there is an effect of the standard rehabilitation program on the improvement of muscle imbalances related to the lower limbs of the control group, the observed difference between means being 19.6, the T-test value is 6.441 for the p < .003 threshold, it denotes statistical significance;

- there is an effect of the proposed rehabilitation program on the improvement of muscular imbalances related to the lower limbs of the experimental group, the observed difference between means being 25.2, the T-test value is 12.096 for the p < .000.

Threshold, it denotes statistical significance, greater significance for the experimental group 0.000 versus 0.003 control group related to muscle imbalances – **Figure 10.15.**

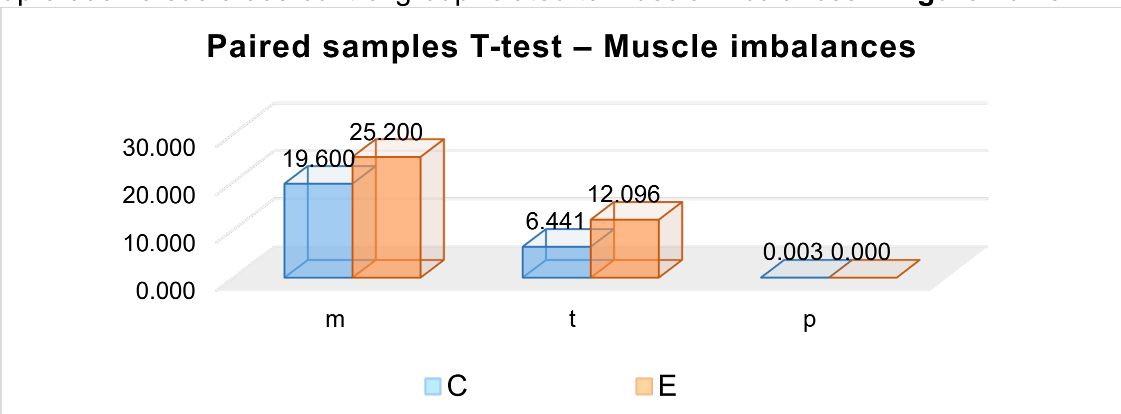


Figure 10.15 Paired samples T-test – Muscle imbalances

4. The Wilcoxon test for two paired samples reveals statistical significance for both programs, each applied to groups of independent patients p <0.05, respectively 0.043 for the standard and the experimental program **- Figure 10.16**.

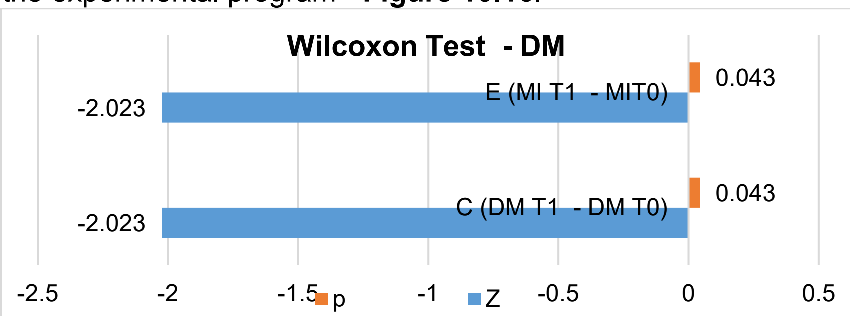


Figura 10.16 Wilcoxon Test - DM

10.5. Heart rate monitoring

Descriptive statistics showed that the measured values (mean/median) during the rehabilitation programs were below the target heart rate values calculated using Karvonen's formula according to the rehabilitation phases for both tested groups, maintaining the effort at an aerobic level.

10.6. Measuring perceived exertion

Both rehabilitation programs kept the same perceived level on a scale from 0 to 10, with an average of 3.6 Borg, which corresponds to a moderate, not very intense level – **Figure 10.17**.

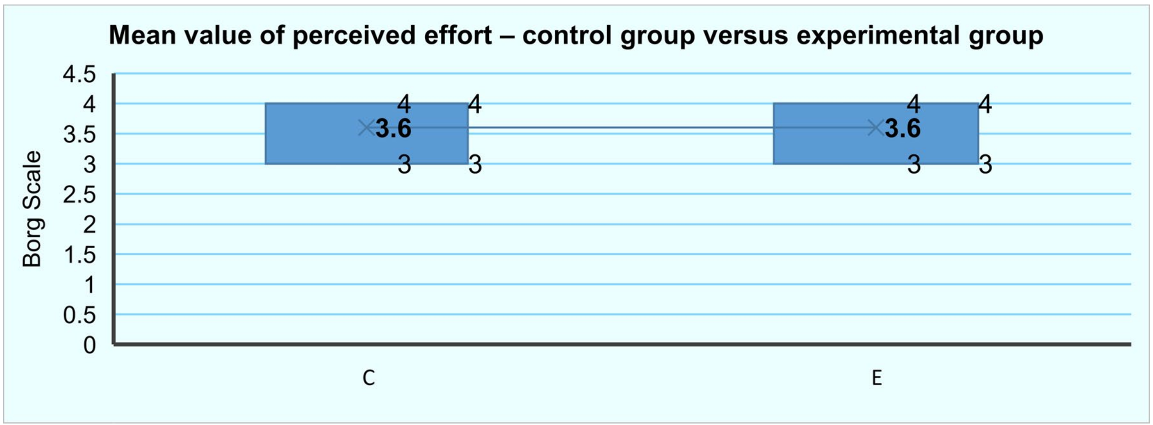


Figure 10.17 Mean value of perceived effort – control group versus experimental group

The conclusion is that the rehabilitation program that included the horizontal stationary bicycle achieved better results in terms of pain control and correction of muscle imbalances related to the lower limbs, with the mention that both programs recorded statistically significant results in terms of functionality.

The final conclusion is that the proposed physical therapy program involving the static horizontal pedal board has proven its efficiency according to the applied statistical tests - **Table 10.1** and in accordance with the objectives related to the rehabilitation protocol and working hypotheses.

Table 10.1 Conclusions Part II

C n=5, 3B, 2F, Average age 58.67 ± 11.67, IMC (kg/m^2) average 28.17±4.50 2 subjects-40% 40-49 a, 1 subject - 20% 50-69 a, 2 subjects – 40% > 70 a						
E n=5, 2B, 3F, Average age 56.67 ± 12.14, IMC (kg/m^2) average 27.32±2.94 2 subjects -40% 40-49 a, 1 subject - 20% 50-69 a, 2 subjects – 40% > 70 a						
Monitoring values: perceived effort 3.6 Borg, RC < RCT (C/E)						
Conclusions Assessements	**VAS**		**Joint Testing**		**Muscle Imbalances**	
Statistics p<.05 CI 95%	C	E	C	E	C	E
Test for two paired samples (p)	.004	.001	.042	.043	.003	.000
Wilcoxon test (p)	.041	.039	.000	.001	.043	.043
Correlation index (r)					0.990	0.997

Formulation of recommendations and proposals for the final research following the results of the preliminary experimental research:

- As much as possible the inclusion of more participants in the final research;
- Evaluation of the quality of life through a validated questionnaire and the statistical interpretation of its results.

PART III CONTRIBUTIONS TO THE IMPROVEMENT OF QUALITY OF LIFE USING THE REHABILITATION PROGRAM DESIGNED FOR THE BUILT STATIC HORIZONTAL PEDAL COMPARISON WITH A STANDARD PROGRAM – FINAL RESEARCH

CHAPTER 11 GENERAL METHODOLOGICAL FRAMEWORK OF THE FINAL RESEARCH

11.1. The premises of the final research

Premises considered as a starting point in carrying out the final research:

- the stationary horizontal pedal system offers the possibility to approach a variable range (minimum - maximum) of the amplitude of movement depending on the individualized program of each patient starting from their pathology;
- the antigravity supine position allows a movement that favors the remission of Celsius signs (*dolor, calor, turgor, rugor*) and functional impotence, contributing to the proper rehabilitation of the lower limbs;
- the recording of transmitted analog values allows the timely correction of muscular and alignment imbalances of the lower limbs;
- the complex system approaches triple flexion/extension simultaneously in interdependence in order to make neuromotor rehabilitation more efficient;
- the rehabilitation program is based on the somatotype of each patient to dose the effort, depending on the body composition (AmazFit).

11.2. Final research objectives

The objectives of the actual (final) research are represented by:

- use of appropriate methods for evaluating the functional deficit and the need for therapeutic intervention;
- development of original recuperative intervention strategies based on the basic pathology, body composition and comorbidities of the patient;
- highlighting the role of the kinetic chain of the triple flexion/extension related to the lower limbs in postural stability, facilitating ambulation, reducing the number of immobilization days;
- identification of recuperative elements specific to pathologies, somatotype and age of the patients, which lead to increasing the efficiency of the implemented protocol strategy;
- establishing the relationship between the application of the recovery protocols and the functional results obtained (initial and final testing);
- the identification of objective and subjective evaluation tools for the evaluation of the quality of life following the application of the standard and proposed recovery protocol.

11.3. The purpose of the final research

The purpose of the final research is to verify the effectiveness of the proposed rehabilitation programs compared to the standard ones, adapted according to the pathology, somatotype, comorbidities, applied with the help of the stationary horizontal pedal board designed and built for the rehabilitation of the lower limbs and to determine their impact on the quality of life.

11.4. Final research tasks

The tasks of the final research established in accordance with the objectives proposed at this level are as follows:

- Establishing the strategy for conducting the final research and drawing up the organization plan for the final research by stages;
- Formulation of the premises and hypotheses of the final research;
- Selection of subjects who participate in the final research in accordance with their informed consent and the rules of professional ethics;
- Establishing the inclusion criteria, the exclusion criteria and the framework of specific evaluation means and processes, the work observations depending on the pathology and the particularities of application depending on the associated pathologies;
- Establishing the final research methods;
- Initial evaluation of the subjects included in the research using computerized technologies - sensors for highlighting muscular imbalances with a diagnostic and therapeutic feedback role, monitoring parameters - determination of body composition, stability score, heart rate and classic instruments - anamnestic data, effort scales, pain perception scales, before the implementation of the standard and proposed medical rehabilitation protocol, using a static horizontal pedal board;
- Conception of the medical rehabilitation protocol and its application;
- Elaboration of rehabilitation programs using stationary horizontal pedals, adapting the structure of the exercise program according to degrees of difficulty depending on the risk profile of the patients and their comorbidities;
- The final evaluation of the subjects at the end of the final research using the battery of tests used in the initial evaluation, the application of the quality of life test;
- Data centralization;
- Analysis, processing and statistical-mathematical, graphic and medical interpretation of the results regarding the measurements performed and the quality of life;
- Highlighting the conclusions of the final research.

11.5. Final research hypotheses

The final research hypotheses are as follows:

1. The medical rehabilitation process can be made more efficient by using the static horizontal pedal system (the efficiency indicators used were the statistical interpretations related to the increase in the amplitude of joint movement, the recovery of muscle strength, the reduction of pain, the control of heart rate and effort);
2. Deconditioning can be avoided by applying the rehabilitation protocol using static horizontal pedals;
3. The quality of life can increase as a result of treatment compliance and the effectiveness of the proposed rehabilitation protocol.

11.6. Subjects and place of the final research

The final research was carried out at the patients' home in accordance with the medical credentials of the free practice cabinet for public activities related to the medical act - Murgoci I. Nicolae - Individual Practice Cabinet - Physiotherapy, registered in the Single Register of Medical Cabinets - part 3 of The Directorate of Public Health of Galati County under no. 096732 /149 of 11.03.2016 **(Annex no. 7),** according to internal decision no. 32/20.10.2021, valid for all works and studies carried out for the preparation of the doctoral thesis.

11.7. Final research stages

The stages of the final research took place as follows:

- The start of the final research – elaboration of premises, objectives, research hypotheses: July 2022
- Initial assessment: ½ April - June 2022 (T0 – T2-10 patients), August – September 2022 (14 patients): pain assessment with the visual analog scale, establishing the patient's riskogram by bioimpedance, joint balance - goniometry, muscle balance - MRC units and assessment of muscle imbalances, expressed in the difference in

average analog value between the lower limbs, cardiac reserve, assessment of perceived effort with the Borg scale;
- Final assessment: October 2022 – February 2023 - pain assessment with the visual analogue scale, establishing the patient's riskogram by bioimpedance, joint balance - goniometry, muscle balance - MRC units and assessment of muscle imbalances, expressed in the difference in average analogue value between the lower limbs, reserve cardiac, assessment of perceived effort with the Borg scale, collection of results following the application of the standard and proposed rehabilitation programs for eight weeks for each patient;
- Testing the quality of life questionnaire RAND SF-36: ½ April - June 2022 (T0 - 10 patients), August - September 2022 (T0 - 14 patients), September 2022 - February 2023 (T2 - 24 patients);
- Data centralization and processing: March 2023;
- Drafting, issuing conclusions April 2023 - May 2023;
- Handing in the final paper: May 2023, in order to submit the doctoral thesis.

11.8. Evaluation of the subjects

The evaluation of the subjects followed the steps from Part II of the work **CHAPTER 6, point 6.8.**, to which was added the performance of the SF-36 quality of life test, the statistical analysis of its results and linear regression tests (beta coefficient) intercorrelated with the battery of functional and monitoring tests for the interpretation of the results.
In order to determine the changes in the quality of life, a generic instrument for quantifying the state of health was used - the Short Form 36 Questionnaire (SF-36), developed by the New England Medical Center within the Medicul Outcomes Study (**Annex no. 4**). This model includes 36 questions and eight scales that aggregate the items into two generic concepts:
- Physical – includes the scales - physical functioning, bodily pain, role limitations due to physical health problems and general health perceptions
- Psychological – includes the scales - role limitations due to personal or emotional problems, emotional well-being, social functioning, energy/fatigue, changes in health status (rand.org, 2022; John E. Ware & Sherbourne, 1992).

The RAND 36-Item Health Survey (Version 1.0) addresses eight health concepts: physical functioning, bodily pain, role limitations due to physical health problems, role limitations due to personal or emotional problems, emotional well-being, social functioning, energy /fatigue and general health perceptions. Additionally includes an article on perceived change in health status (Hays RD, 1992; Ware JE Jr, 1992).

Scoring the RAND 36-Item Health Survey is a two-step process. First, the precoded numeric values are recoded according to the default scoring key. All items are scored such that a high score defines a more favorable state of health. In addition, each item is scored on a range from 0 to 100, such that the lowest and highest possible scores are 0 and 100, respectively. Scores represent the percentage of the total possible score obtained. In step 2, items from the same scale are quantified together to create the 8 scale scores. Therefore, the scores represent the average of all items on the scale for which the respondent ticked the answer. Information about the reliability, central tendency, and variability of the scales using this method denotes the safety of its use (Anita L. Stewart, 1992; Hays RD, 1992; John E. Ware & Sherbourne, 1992).

Originally published in 1992 in Medical Care, the 36-item Health Survey Short Form (SF-36) generically assesses quality of life. The presented version is known as the RAND SF-36 which covers eight health domains: physical functioning (10 items), bodily pain (2 items), role limitations due to physical health problems (4 items), role limitations due to personal problems or emotions (4 items), emotional well-being (5 items), social functioning (2 items), energy/fatigue (4 items) and general health perceptions (5 items). Scores for each domain range from 0 to 100, with a higher score defining a more favorable state of health. SF-36 – OrthoToolKit was used to quantify the results.

CHAPTER 12. MEDICAL REHABILITATION RELATING TO THE CONTROL GROUP AND THE EXPERIMENTAL GROUP FOR THE PURPOSE OF AMBULATION FACILITY

12.1. Presentation of the subjects and the results of the evaluations of the control group and the experimental group

12.1.1. Presentation of the subjects and their specific demographic characteristics

The control group and the experimental group included 12 subjects each, and to preserve the homogeneity of the study, 24 patients with similar basic impairment were selected from 52 patients to respect the principle of data comparability - **Table 12.1**.

Each group contains 2 patients with coxo-femoral joint damage, 2 patients with stroke, 5 patients with knee joint damage and 3 patients with ankle joint damage. All patients included in the study had a mild to moderate episode of COVID-19 that did not require hospitalization or oxygen therapy.

The rehabilitation program lasted 8 weeks with a frequency of 3 times a week, in total 24 sessions (50 min/session).

Tabelul 12.1 **Presentation of the subjects**

No	Diagnostic	T	C/E	Subjects	Age	Gender	G	Î	IMC	IMC Result
1	Right coxarthrosis, Lumbosciatica	T1	C	C.N.	45	M	90	1.79	27.93	Overweight
2	Left ankle postfracture status	T1	E	P.E.	44	F	59	1.64	22.03	Normal
3	Right coxarthrosis, L4-L5 disc herniation stage II	T1	E	A.J.	43	M	99	1.74	32.57	Obesity
4	Rheumatoid polyarthritis, coxarthrosis, gonarthrosis, HTAE stage 2, hypothyroidism, dyslipidemia	T1	E	I.A.	73	F	73	1.60	28.32	Overweight
5	Left ankle post sprain status	T1	C	B.I.	78	M	70	1.70	24.10	Normal
6	Left medial meniscus injury - rupture of the vascular area	T2	C	V.I.	40	F	58.85	1.69	20.61	Normal
7	Gonarthrosis grade 2, BIT proximal tendinopathy, rickets sequelae, left genu valgum, scoliosis	T2	E	P.C.	50	M	89	1.84	26.24	Overweight
8	Severe disease (achile tendon traction apophysitis), rickets sequelae, bilateral ankle valgus genu, scoliosis	T2	C	B.A.	38	F	48.50	1.75	15.84	Overweight
9	Right knee meniscus tear	T2	E	C.R.	39	M	74	1.76	23.81	Normal
10	Injury - grade 2 dislocation extraarticular medial collateral ligament	T2	E	I.N.	42	M	88	1.80	27.28	Overweight
11	Distal BIT tendinitis, bilateral flat tip, rickets sequelae	T2	C	A.M.	38	M	53.90	1.70	18.65	Normal
12	Ischemic stroke, left hemiplegia	T1	C	G.L.	53	F	54	1.58	21.57	Normal
13	Gonathrosis, Dyslipidemia, HTAE stage 3	T1	C	O.P.	74	M	104	1.68	36.88	Obesity
14	Right coxarthrosis, Disc herniation stage II L4-L5, lumbago, dyslipidemia, HTAE stage 2	T2	C	M.T.	66	F	80.90	1.60	31.60	Obesity
15	Ischemic stroke, left hemiparesis	T1	E	D.E.	52	M	88	1.78	27.80	Overweight
16	Ischemic stroke, dysarthria, mixed aphasia, right hemiplegia, HTAE stage 3, dyslipidemia	T2	E	R.D.	53	F	106	1.64	39.50	Obesity
17	Postfracture status open, reduced with osteosynthesis, left tibia and fibula	T1	C	G.V.	49	F	82	1.64	30.60	Obesity
18	Status after multiple fractures: left femur 1/2 diaphysis, greater trochanter and acetabulum, left clavicle fracture, left humerus, DZ type I, BCR stage IV, amaurosis left eye, operated cataract right eye, parathyroidectomy, angioplasty with 3 stents, cardiomegaly	T2	E	I.D.	31	F	51	1.56	21.10	Normal
19	Patellar tendinitis, LIP tear after car accident (board injury)	T2	E	N.C.	34	M	70	1.68	24.77	Normal
20	Right ankle postluxation status	T1	E	S.C.	76	F	70	1.66	25.40	Overweight
21	LIA injury – tear, fracture Second	T2	C	P.M.	46	M	87.75	1.80	27.30	Overweight
22	Status post uncemented total hip prosthesis, cervical pain, lumbar discopathy	T2	E	B.C .	60	F	91	1.58	36.61	Obesity
23	Lumbargia, prepatellar bursitis	T2	C	D.N.	32	M	57.00	1.79	17.79	Overweight
24	Ischemic stroke, left hemiparesis, left femoral neck fracture, status post left knee prosthesis	T2	C	N.A.	58	M	85.90	1.79	26.81	Overweight

BIT = iliotibial band; HTAE = essential hypertension; BCR = chronic kidney disease; LIP = posterior cruciate ligament; LIA= anterior cruciate ligament; AVC = stroke; T= evaluation time interval; T1 = subjects who were also part of the initial experimental group (evaluation after 4 weeks); T2= final experiment (after 8 weeks); C= control group; E = experimental grup; M= man; F = woman; G= weight; Î=height; IMC = BMI = body mass index;

The presentation of the subjects included, in addition to the main diagnosis and associated comorbidities, the type of patient coded with C or E depending on the control group or the experimental group, age, gender and interpretation of the body mass index.

12.1.2. Evaluation of pain before and after the application of physiotherapy programs at the level of the control group and the experimental group

The interpretation of the results of the visual analog scale of pain by numerical association respected the following standardization: 0- no pain, 1-3 mild pain, 4-7 moderate pain, 8-10 severe pain. The moment T0 was considered the one before the start of the recovery therapy and the moment T2 after eight weeks of applying the recovery program related to the control group, respectively the experimental group according to **Table 12.2**.

Tabelul 12.2 Evaluation of pain before and after the application of physiotherapy programs at the level of the control group and the experimental group

No	Type	Subjects	VAS T0	VAS T2
1	C	C.N.	6	1
2	C	B.I.	5	2
3	C	G.L.	4	0
4	C	O.P.	6	1
5	C	G.V.	7	2
6	C	V.I.	6	1
7	C	B.A.	4	1
8	C	A.M.	5	2
9	C	M.T.	7	3
10	C	P.M.	6	1
11	C	D.N.	5	1
12	C	N.A.	6	2
13	E	P.E.	6	0
14	E	A.J.	7	1
15	E	I.A.	5	2
16	E	D.E.	4	0
17	E	S.C.	5	0
18	E	P.C.	6	2
19	E	C.R.	5	1
20	E	I.N.	4	0
21	E	R.D.	5	1
22	E	I.D.	7	2
23	E	N.C.	5	0
24	E	B.C .	5	1

C - control; E - experiment

12.1.3 Joint balance - goniometry before and after the application of the physiotherapy programs at the level of the control group and the experimental group

The articular balance (BA) performed by goniometry before and after the application of the physiotherapy programs at the level of the control group and the experimental group concerned the coxo-femoral joint (CF), the knee joint (G) and the ankle joint (GZ) related to the left affected limb or right depending on the pathology. Flexion was evaluated for the hip and knee joint and both flexion and extension for the ankle. Gained range of motion was assessed separately as the difference between time T2 and time T0. For each patient, the most affected joint(s) was marked in degrees, according to **Table 12.3**.

Tabelul 12.3 Joint balance - goniometry before and after the application of the physiotherapy programs at the level of the control group and the experimental group (degrees)

Subiecti	tip	BA CF T0	BA G T0	BA GZ F T0	BA GZ E T0	BA CF T1	BA G T1	BA GZ F T1	BA GZ E T1	BA CF T2	BA G T2	BA GZ F T2	BA GZ E T2
1.C.N.	C	60	100	15	35	75	120	19	45	85	125	20	50
2.B.I.	C	85	120	5	34	90	130	11	40	90	130	17	45
3.G.L.	C	40	80	3	27	60	100	7	32	70	110	14	35
4.O.P.	C	75	75	10	43	85	90	15	49	85	105	17	50
5.G.V.	C	75	90	8	38	90	110	16	44	90	120	19	47
6.V.I.	C	85	55	20	35	90	75	20	45	90	115	20	47

7.B.A.	C	75	95	10	15	80	115	15	25	85	120	17	35
8.A.M.	C	60	85	15	35	75	95	17	40	85	115	19	45
9.M.T.	C	55	65	10	25	72	85	15	35	80	110	17	42
10.P.M.	C	60	35	7	22	71	50	12	27	78	82	16	43
11.D.N.	C	52	56	15	32	65	72	15	37	81	98	17	46
12.N.A.	C	35	25	3	10	42	45	7	15	55	65	15	23
13.P.E.	E	90	110	6	23	90	120	13	43	90	125	16	49
14.A.J.	E	55	95	12	32	78	125	17	42	82	128	18	46
15.I.A.	E	45	55	5	28	55	70	10	36	66	85	15	46
16.D.E.	E	35	75	3	29	60	92	8	42	72	100	11	45
17.S.C.	E	80	115	4	31	90	125	11	46	90	130	17	49
18.P.C.	E	42	45	13	29	58	62	15	32	71	105	17	42
19C.R.	E	75	35	15	38	80	55	17	42	90	125	20	50
20.I.N.	E	62	47	12	35	75	65	15	42	90	115	19	47
21.R.D.	E	35	42	3	10	55	56	7	15	65	72	11	24
22.I.D.	E	32	67	10	20	57	86	15	32	75	92	17	41
23.N.C.	E	65	37	12	26	70	45	15	37	85	109	19	46
24.B.C .	E	55	72	2	15	65	89	12	25	72	92	15	38

C= control group; E = experimental group; BA = joint testing; CF = coxo-femoral joint; G = knee; Gz = ankle

12.1.4. Muscle balance before (T0) and after (T2) the application of physical therapy programs at the level of the control group and the experimental group and the highlighting of muscle imbalances between the left and right lower limb

The muscle balance tests a relative maximum force at a given moment with the manual muscle testing method - the MRC Medical Research Council scale with 6 levels (0-5) for each muscle group of the lower limb. Thus, thigh flexion, knee extension, dorsiflexion/ankle extension were recorded before (BM T0) and after (BM T2) the application of physiotherapy sessions for 8 weeks. In **Table 12.4**, the most affected muscle group was recorded according to the pathology of each patient.

Muscular imbalances were evaluated with the static horizontal pedal system and expressed in similar average values for the right and left lower limb. The differences between the lower limbs before (Dif VAM T0) and after (Dif VAM T2) were highlighted. For the control group, a 3-minute pedaling session was performed with a controlled moderate effort for evaluation purposes only, in contrast to the experimental group where pedaling had both a therapeutic and evaluation role.

Tabelul 12.4 Muscle balance before (T0) and after (T2) the application of physical therapy programs at the level of the control group and the experimental group and the highlighting of muscle imbalances between the left and right lower limb

Nr, crt	Subiecti	BM T0	BM T1	BM T2	Dif VAM T0	Dif VAM T1	Dif VAM T2
1	C.N.	4	5	5	32	20	15
2	B.I.	4	5	5	26	10	5
3	G.L.	2	3	4	84	55	32
4	O.P.	3	4	5	42	25	19
5	G.V.	3	4	5	56	32	9
6	V.I.	3		5	35		19
7	B.A.	3		5	55		36
8	A.M.	4		5	62		32
9	M.T.	3		4	72		36
10	P.M.	4		5	56		29
11	D.N.	4		5	36		17
12	N.A.	2		3	89		42
13	P.E.	3	5	5	39	12	7
14	A.J.	4	5	5	43	18	11
15	I.A.	3	4	5	30	8	5
16	D.E.	2	3	4	107	75	41
17	S.C.	4	5	5	29	9	4
18	P.C.	4		5	62		12
19	C.R.	3		5	59		7
20	I.N.	4		5	47		10
21	R.D.	2		4	92		36
22	I.D.	4		5	83		46
23	N.C.	4		5	55		23
24	B.C .	3		5	48		31

Remark - Patients (N=10) who were included in the experimental program are marked in gray. Later, the 14 patients were included in the final study.

12.1.5 Monitoring values of perceived effort (BORG scale) and heart rate during the application of physiotherapy programs at the level of the control group and the experimental group

The heart rate reserve as well as the target heart rate according to the recovery program used Karvonen's formula: Target heart rate (FC) = [(Maximum FC - Resting FC) × % Intensity] + Resting FC (Tudor Sbenghe, 2002, p. 569).

A gradual intensity of 40-60% was proposed, in this way not exceeding the lactate threshold.

Heart rate monitoring was performed with the Huawei Watch GT 2 Smartwatch according to **Table 12.5**, taking into account the phases of rehabilitation – 24 sessions in total, distributed 4 for each of the 3 levels of intensity of the recuperative treatment for the first month of rehabilitation and maintaining the maximum intensity of pedaling in the last month with the progressive resumption of daily tasks.

Maximum heart rate was set as the interval between an upper limit determined as FCM1 = maximum heart rate 1 = (220-age) and a lower limit determined as FCM2 = maximum heart rate 2 = (215- age *0.66), for each limit calculating the control target vardiac frequency.

Chronotropic deficit - DC % = Chronotropic deficit % = [(Pmxt- Pmxef)/ Pmxt]*100 (Tudor Sbenghe, 2002, p. 569) represents an important index to determine the actual maximum heart rate recorded during exercise and its relative value to the theoretical maximum heart rate for the patient's age. Depending on the pedaling intensity, the reduction must increase so that the contraction power of the cardiac muscle reaches the theoretical potential, under the conditions of maintaining the aerobic effort.

Table 12.5 Heart rate monitoring values during the application of physical therapy programs at the level of the control group and the experimental group

Subjects	V	FCR	FCM 1	FCM 2	FCT2 (I=40%)	FCT2 (I=50%)	FCT2 (I=60%)	FC 1	FC 2	FC 3	DC 1	DC 2	DC	Decreasing DC
1.C.N.	45	75	175	185	119	130	141	118	129	137	31.93%	25.63%	21.71%	10.22%
2.B.I.	78	80	142	164	110	122	130	105	111	126	22.25%	14.25%	11.27%	10.98%
3.G.L.	53	77	167	180	117	129	139	115	127	137	29.94%	23.05%	17.96%	11.97%
4.O.P.	74	90	146	166	111	128	136	110	126	134	23.65%	12.27%	8.22%	15.44%
5.G.V.	49	67	171	183	118	125	136	116	124	133	30.96%	27.00%	22.22%	8.73%
6.V.I.	40	72	180	189	120	130	142	118	125	139	33.09%	27.61%	22.78%	10.31%
7.B.A.	38	69	182	190	121	129	142	119	127	140	33.53%	28.87%	23.08%	10.46%
8.A.M.	38	75	182	190	121	132	144	120	129	139	33.53%	27.22%	23.63%	9.91%
9.M.T.	66	68	154	171	114	120	130	111	115	124	26.25%	22.26%	19.48%	6.77%
10.P.M.	46	81	174	185	119	133	143	117	130	139	31.69%	23.67%	20.11%	11.58%
11.D.N.	32	65	188	194	123	129	142	121	125	138	34.81%	31.15%	26.60%	8.22%
12.N.A.	58	76	162	177	116	126	136	114	123	133	28.59%	22.00%	17.90%	10.69%
13.P.E.	44	80	176	186	119	133	144	116	127	141	32.17%	24.44%	19.89%	12.28%
14.A.J.	43	75	177	187	120	131	142	118	129	141	32.40%	26.10%	20.34%	12.06%
15.I.A.	73	65	147	167	112	116	126	106	113	123	23.99%	21.15%	16.33%	7.67%
16.D.E.	52	70	168	181	117	125	136	114	123	135	30.20%	25.39%	19.64%	10.55%
17.S.C.	76	85	144	165	111	125	133	110	123	131	22.96%	13.25%	9.03%	13.93%
18.P.C.	50	67	170	182	118	125	136	115	123	134	30.71%	26.76%	21.18%	9.53%
19.C.R.	39	78	181	189	121	134	145	120	131	143	33.31%	26.17%	20.99%	12.32%
20.I.N.	42	75	178	187	120	131	142	119	129	139	32.63%	26.33%	21.91%	10.72%
21.R.D.	53	69	167	180	117	125	136	115	122	135	29.94%	25.44%	19.16%	10.77%
22.I.D.	31	79	189	195	123	137	148	121	136	145	35.02%	27.63%	23.28%	11.74%
23.N.C.	34	83	186	193	122	138	149	120	135	147	34.40%	25.92%	20.97%	13.43%
24.B.C .	60	78	160	175	115	127	136	111	123	134	28.03%	20.81%	16.25%	11.78%

FCR=Resting heart rate, FCM1 = Maximum heart rate (220-age), FCM2 = Maximum heart rate (215-age*0.66) [17]; C = control; E = experiment
FCT1=Target heart rate 1= [(Maximum FC1 – Resting FC) ×40% Intensity] + Resting FC, afferent phase 1, 2 (I=50%), 3 (I=60%)
FCT2= Target heart rate 2= [(Maximum FC2 – Resting FC) ×40% Intensity] + Resting FC, afferent phase 1, 2 (I=50%), 3 (I=60%)
I = Effort Intensity (40%,50%;60%); V = Age
FC1,2,3 = frecvenţele cardiace măsurate în funcţie de faza reabilitării
DC % = deficit cronotropic % = [(Pmxt- Pmxef)/ Pmxt]*100

The Borg scale, graded from 1 to 10, reveals the perception of pedaling effort and was used to establish the initial basic rhythm that corresponds to an intensity level agreed by the patient, the conditioning being aerobic. For recovery, the level of perceived effort must not exceed the moderate level: Borg = 4-6, in order not to reach the lactate threshold. The monitoring values of the perceived effort (BORG scale) during the application of the physiotherapy programs at the level of the control group and the experimental group are highlighted in **Table 12.6**.

In the recuperative protocols of patients after remission of the acute episode, a maximum score on the Borg scale of 4/10 is indicated for cardiopulmonary control (dyspnea and fatigue), according to the post-Covid rehabilitation protocol (EMITENT MINISTERUL SĂNĂTĂȚII, 2021). I note that every patient had at least one mild to moderate COVID-19 episode that did not require hospitalization or oxygen therapy, 22 patients being vaccinated and two patients not vaccinated.

Table 12.6 Monitoring values of the perceived effort (BORG scale) during the application of physiotherapy programs at the level of the control group and the experimental group

No	Type	**Subjects**	**BORG T1**	**BORG T2**
1	C	C.N.	4	4
2	C	B.I.	3	2
3	C	G.L.	4	3
4	C	O.P.	3	3
5	C	G.V.	4	3
6	C	V.I.	4	3
7	C	B.A.	3	3
8	C	A.M.	3	2
9	C	M.T.	4	4
10	C	P.M.	3	3
11	C	D.N.	4	2
12	C	N.A.	4	4
13	**E**	**P.E.**	**4**	**2**
14	**E**	**A.J.**	**4**	**2**
15	**E**	**I.A.**	**3**	**3**
16	**E**	**D.E.**	**4**	**3**
17	**E**	**S.C.**	**3**	**2**
18	**E**	**P.C.**	**4**	**4**
19	**E**	**C.R.**	**4**	**3**
20	**E**	**I.N.**	**3**	**2**
21	**E**	**R.D.**	**4**	**4**
22	**E**	**I.D.**	**4**	**4**
23	**E**	**N.C.**	**3**	**2**
24	**E**	**B.C .**	**4**	**3**

C - control; E - experiment

The perceived effort was evaluated for the control group and the experimental group after performing the standard and proposed physical therapy program during the 24 sessions held over 8 weeks.

12.1.6. Values resulting from the bioimpedance analysis of the subjects

Body composition measurements obtained by bio-impedance used the Amazfit Smart Scale - Body Composition Analyzer (Declaration of Conformity with directives 2014/53/EU and 2014/65/EU) from the practice's own endowment, using a single frequency of 50 kHz. For each subject, the major body compartments determined as a tissue system were determined, automatically estimated by linear empirical equations stored in the system memory together with personal physical data (age, weight, height) – **Table 12.7.**

- Exclusion criteria related to bioimpedance measurements included all situations of alteration of hydroelectrolyte balance (hepatic, renal, decompensated heart diseases), acute-contagious infections, subjects wearing pacemakers, people with skin lesions and pregnant women.
- Inclusion criteria related to bioimpedance measurements targeted any patient with a medical indication for physical therapy from the specialist doctor; restrict the consumption of food and liquids for at least 4 hours and alcohol for at least 8 hours before the test.

• Procedure: subjects in orthostatism with bare feet in contact with the conductive surface

Table 12.7 Values resulting from the bioimpedance analysis of the subjects

No	C/E	N	FM (Kg)	SM (Kg)	FFM (Kg)	Apă (l)	Protein (Kg)	Bone tissue (Kg)
1	C	C.N.	26.22	34.7	59.76	45.11	11.46	3.20
2	C	B.I.	16.72	27.30	50.13	36.29	11.14	2.70
3	C	G.L.	15.45	19.90	36.25	27.36	6.89	2.00
4	C	O.P.	40.08	35.1	60.45	45.60	11.56	3.30
5	C	G.V.	33.76	22.5	40.49	30.47	7.43	2.6
6	C	V.I.	17.89	21.40	38.71	29.19	7.12	2.40
7	C	B.A.	2.91	21.40	40.18	29.10	8.68	2.40
8	C	A.M.	2.70	26.4	48.41	35.14	10.56	2.70
9	C	M.T.	35.68	23.9	42.75	32.20	7.85	2.70
10	C	P.M.	24.48	33.2	59.89	43.35	13.34	3.2
11	C	D.N.	3.88	27.5	50.22	36.42	11.00	2.80
12	C	N.A.	23.45	32.7	59.12	42.78	13.14	3.20
13	E	P.E.	17.78	21.8	39.19	29.57	7.23	2.40
14	E	A.J.	33.92	36.20	62.15	46.98	11.77	3.40
15	E	I.A.	30.23	22.30	39.91	30.16	7.25	2.50
16	E	D.E.	24.10	31.7	54.90	41.45	10.45	3
17	E	S.C.	24.99	19.2	34.92	26.41	6.51	2
18	E	P.C.	23.90	34.20	61.41	44.51	13.59	3.30
19	E	C.R.	31.42	22.30	40.04	30.16	7.38	2.50
20	E	I.N.	18.74	34.70	66.18	45.08	17.59	3.50
21	E	R.D.	49.96	30.6	41.54	40.18	9.78	3.2
22	E	I.D.	14.48	18.2	34.92	25.26	7.65	2
23	E	N.C.	14.19	28.9	52.74	38.17	11.67	2.9
24	E	B.C	43.42	25.6	45.39	34.18	8.41	2.80

The values resulting from the bio-impedance analysis of body composition highlighted adipose tissue (FM), skeletal muscles (SM), non-adipose tissue (FFM), the amount of protein and bone tissue, expressed in kilograms and the amount of water expressed in liters for all patients included in the study. Following the statistical analysis of these indicators, a risk profile was established for each subject, followed by an individualized dosage of the therapeutic exercise.

An excess of adipose tissue constitutes a high metabolic risk, insulin resistance, comorbidities associated with obesity, cardiac and respiratory diseases that lead to difficulties in performing daily tasks. If patients also present a concomitant decrease in non-adipose tissue (proteins, intracellular and extracellular water and bone minerals), the risk multiplies (risk of fractures/falls, decreased quality of life, disabilities and mobility) so that resistive, concentric therapeutic exercises are necessary of minimum-medium intensity over a longer period. Instead, a balanced somatotype allows performing eccentric and resistive exercises with maximum intensity (MURGOCI, 2021; Murgoci, Mereuță, et al., 2022).

12.2.4. The medical rehabilitation program adapted to the control and experimental group

The medical rehabilitation program adapted to the control and experimental group complies with the recuperative protocol presented in Chapter 8, the detailed content of the recovery programs being according to **Tables 12.30, 12.31** with the specification that all patients had at least one mild to moderate COVID-19 episode. (**Annex no. 8**)

Table 12.30 Detailed content of the rehabilitation program adapted to the control group

Standard physical therapy program content adapted to each condition (minutes) n=12	Gonartroză, Coxartroză, lombosciatica (origine mecanica) 3 subiecţi	AVC ischemic hemiplegie/hemipareză 2 subiecţi	Status post-traumatism MI 7 subiecţi
Therapeutic massage	15	15	
Manual lymphatic drainage			15
Invessie table positioning	5		
Specific exercises*	20		
Postural treatment - Positions at the edge of the bed in a short sitting position		5	
FNP – Kabat (5 min passive, 5 min active)		10	5
Passive, passive-active physiotherapy		10	20
Manual therapy & stretching	10	10	10
Total time (minutes) of which	50	50	50
active	20	5	15
passive	30	40	35
active pause	0	5	0

*** Details of specific exercises**

-Gonarthrosis, Coxarthrosis and lumbosciatica of mechanical origin with associated lordosis - medical recommendation - **Wiliams program, 5-7-10 repetitions (progressive increases every 4 sessions, total 24 sessions)**

Specific exercises

- from the supine position, bend and extend the knees alternately;
- from the supine position, flexion of the thigh on the abdomen is performed alternately, holding for 10 seconds, followed by returning with the lower limbs extended and then resuming the movement with simultaneous execution;
- from the supine position, hands behind the back of the head, feet on the ground, flexion of the thigh on the abdomen is performed alternately, holding for 10 seconds, followed by returning with the lower limbs extended;
- from the supine position, with the arms stretched above the head and the knees bent, the lumbar area is glued to the floor, contracting the abdominal muscles;
- from the supine position with bent knees and feet on the ground, rotate the pelvis to the left, respectively to the right;
- from the supine position with the lower limbs extended, place the heel on the opposite knee and leave the thigh on the ground, then return to the initial position;
- from the supine position, raise one leg at a time above the ground, hold for 10 seconds, then return to the initial position;
- from the supine position with a pillow under the head, hips and knees flexed, feet on the ground, contracting the gluteal and abdominal muscles, tilt the pelvis by lifting the buttocks off the ground. Gradually perform the same movements with the knees less and less bent.

- Stroke hemiplegia/associated hemiparesis/ Lower limb post-trauma status
Specific exercises

Neuroproprioceptive facilitation techniques were applied (Beckers & Buck, 2021, p. 145-166) passive, passive-active physical therapy, **5-7-10 repetitions (progressive increases every 4 sessions, total 24 sessions)**

Specific exercises:
- Flexion-abduction-internal rotation(Beckers & Buck, 2021, p. 145);
- Flexion-abduction – internal rotation with knee flexion(Beckers & Buck, 2021, p. 148);
- Flexion-abduction – internal rotation with knee extension (Beckers & Buck, 2021, p. 149);
- Extension-adduction-external rotation (Beckers & Buck, 2021, p. 151);
- Extension-adduction-external rotation with knee extension (Beckers & Buck, 2021, p. 154);
- Extension-adduction-external rotation with knee flexion (Beckers & Buck, 2021, p. 156);
- Flexion-adduction-external rotation (Beckers & Buck, 2021, p. 157);
- Flexion-adduction-external rotation with knee flexion (Beckers & Buck, 2021, p. 159);
- Flexion-adduction-external rotation with knee extension (Beckers & Buck, 2021, p. 161);
- Extension-abduction-internal rotation (Beckers & Buck, 2021, p. 162);
- Extension-abduction-internal rotation with knee extension (Beckers & Buck, 2021, p. 165)
- Extension-abduction-internal rotation with knee flexion (Beckers & Buck, 2021, p. 166)

Table 12.31 Detailed content of the rehabilitation program adapted to the experimental group

Content of the proposed physical therapy program adapted to each condition (minutes) n=12	Coxarthrosis, lumbosciatica (mechanical origin) osteoarthritis 2 subjects	Coxarthrosis/ Gonarthrosis, lumbosciatica (mechanical origin) 3 ischemic	Stroke subjects 2 subjects	Post-trauma MI 2 subjects	Post-trauma MI 1 subject	Post-trauma MI 2 subjects
Therapeutic massage	5	5	5			
Manual lymphatic drainage				8	4	4
Invessie table positioning	4	5				
Static horizontal pedaling-adapted programs A/B/C	31	35	31	27	31	35
Postural treatment - Positioning at the edge of the bed in short sitting			4			
FNP – Kabat-active				5	5	5
Manual therapy, stretching	10	5	10	10	10	6
Total time (minutes)	**50**	**50**	**50**	**50**	**50**	**50**
active	**22**	**26**	**22**	**23**	**27**	**31**
passive	**19**	**15**	**15**	**18**	**14**	**10**
active pause			**4**			
passive pause	**9**	**9**	**9**	**9**	**9**	**9**

The total time of the sessions is 50 minutes, of which pedaling includes 27-35 minutes depending on the associated risk.

CHAPTER 13. EVALUATION OF THE QUALITY OF LIFE OF THE CONTROL AND EXPERIMENTAL GROUP

13.1. The concept of quality of life (QoL)

The concept of quality of life, accepted as a medical term in the Index Medicus in 1977, refers to the general satisfaction induced by the well-being experienced by a person. It is a subjective term and the way of evaluation depends on a person's education, beliefs, values and short/medium and long term goals. Various factors can be considered benchmarks, for example physical health, emotional well-being, social relationships, professional career, financial stability, education, family, cultural factors and leisure.

The quality of life is also correlated with the way a person perceives his physical, mental and social state of health under the conditions of the challenges of external and internal factors so that a state of balance is maintained (ro.wikipedia.org, 2022; The Association of Faculties of Medicine of Canada, 2022). In addition to medical services, individual effort is an important pillar, prevention being a key factor in the prevention of obesity, type II diabetes and heart diseases due to the fact that behavioral factors influence 40% of the number of premature deaths and social factors 15%. (Barnes et al., 2012; Farshad Fani Marvasti, 2012).

The state of mental health has also been defined by the term well-being (Naci & Ioannidis, 2015).

13.2. Questionnaire Short Form 36 (SF-36)

The Short Form 36 Questionnaire (SF-36) is a self-report instrument that uses numerical scoring systems. It can be completed by the patient/family member or a health care professional (doctor, physiotherapist, medical/maternal/social worker, dietician). This particular approach evaluates physical and mental dimensions before and after eight weeks of therapeutic interventions on the same sample of 24 patients **(Annex No. 4).**

The Short Form 36 Questionnaire (SF-36) is a generic instrument for measuring health status, emphasizing the impact of medical interventions, developed and tested by the New England Medical Center in the Medical Outcomes Study (John E Ware et al., 1993; Walters, 2009). The development of the Romanian version was carried out in accordance with the instructions applied at the international level, with the recommendations and under the control of the New England Medical Center (Cotârlă, 2009; J. E. Ware, 2000b). SF-36 has the most evidence of responsiveness, being the most frequently used and evaluated questionnaire (Garratt et al., 2002; Hand, 2016).

The 36-item questionnaire covers eight health domains: physical functioning PF (10 items), bodily pain BP (2 items), role limitations due to physical health problems RP (4 items), role limitations due to personal problems or emotional RE (4 items), emotional well-being MH (5 items), social functioning SF (2 items), energy/fatigue VT (4 items), and general health perceptions GH (5 items). Scores for each domain range from 0 to 100, with a higher score defining a more favorable state of health. RAND SF-36 version 1 was used to quantify outcomes in the SF-36 OrthoToolKit which contains an additional dimension – health change – Health Change HC (1 item). The RAND 36-Item Health Survey 1.0 score uses precoded numerical values quantified by item to derive the nine domains of interest (Anita L. Stewart and John E. Ware, 1992; orthotoolkit.com, 2022; John E. Ware & Sherbourne, 1992).

13.3. Work procedure and method of collecting evaluation results

13.3.1. Working procedure

Patients were entered into the rehabilitation program immediately after discharge to home. At T0 before the start of the rehabilitation program was the first assessment with the SF-36 OrthoToolKit and after eight weeks of physical therapy was the 2nd assessment, considered at the T2 period.

The rehabilitation program lasted 8 weeks with a frequency of 3 times a week, in a total of 24 sessions (50 min/session) of which static horizontal pedaling for 27, 31 or 35 minutes corresponding to the associated risk (for the group of experiment), to which specific individual exercises were added depending on each pathology with the progressive increase in intensity every four sessions for the first month of treatment. During the second month of rehabilitation, the last agreed intensity according to the BORG scale was maintained, followed by its reevaluation, the patient being encouraged to resume daily, professional, social, family tasks. The innovative horizontal bike system was stabilized for supine use and pressure sensors were attached to the pedals to monitor triple flexion/extension kinetic chain parameters (Murgoci, Mereuţă, et al., 2022).

13.3.2. How to collect assessment results with the SF-36 OrthoToolKit

The results of the SF-36 OrthoToolKit application were collected at T0 (before the start of the rehabilitation program) and at T2 (after eight weeks of physiotherapy).

At T0, before the start of the rehabilitation program, the first assessment with the SF-36 OrthoToolKit using the RAND SF-36 version 1 for 24 patients included in the final research (12 patients in the control group and 12 patients in the experimental group), followed by a another assessment at T2 after 8 weeks of rehabilitation. Scores for each domain range from 0 to 100, with a higher score defining a more favorable state of health.

Step 1 and Step 2 are per SF-36 scoring instructions. Step 3 represents the personal contribution, evaluation modality also presented in the study of the analysis of the results of the quality of life after the application of a therapeutic program related to the rehabilitation of the lower limbs with a horizontal bicycle (Murgoci, 2023).

→**Step 1** The 36 items record values for the last four weeks before T0/T2, for questions 3-32 and for the rest of items 1 and 2 at the time of completing the questionnaire, as follows:
- items numbered 1, 2, 20, 22, 34, 36 have five answer categories, interval 100-0, measure degree 25;
-items numbered 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 have three response categories, range 0-100, degree of measure 50;
- articles numbered 13, 14, 15, 16, 14, 18, 19 have two response categories, scale 0-100;
-items numbered 21, 23, 26, 27 and 30 have six answer categories, interval 100-0, measure degree 20;
-items numbered 24, 25, 28, 29 and 31 have six answer categories, range 0-100, measure degree 20;
-items numbered 32, 33 and 35 have five answer categories, range 0-100, measure degree 25.

→**Step 2** The elements from step 1 are quantified to form scales:
-PF - physical functioning, composed of 10 items after recording the average of questions 3, 4, 5, 6, 7, 8, 9, 10, 11, 12;
-RP - role limitations due to physical health problems, composed of 4 items, after recording the average of questions 13, 14, 15, 16;
-RE - role limitations due to personal or emotional problems, composed of 3 items, after recording the average of questions 17, 18, 19;
-VT - energy/fatigue (vitality), composed of 4 items, after recording the average of questions 23, 27, 29, 31;
-MH - emotional well-being (mental health), composed of 5 items, after recording the average of questions 24, 25, 26, 28, 30;
-SF - social functioning, composed of 2 items, after recording the average of questions 20, 32;
-BP – pain (body pain), composed of 2 items, after recording the average of questions 21, 22;
-GH - general state of health, composed of 5 items, after recording the average of questions 1, 33, 34, 35, 36;
-HC - health change, 1 item – number 2.

→**Step 3** The RAND SF-36 version 1 is a generic instrument, so its components target physical and mental status.

The physical summary component (PCS) comprises average physical functioning (PF), role limitations due to physical health problems (PR), and bodily pain (BP) and perceived general health (GH) scores.

The mental summary component (MCS) comprises the mean of role limitations due to personal or emotional problems (RE) and energy/fatigue or vitality (VT), emotional well-being or mental health (MH), and social functioning (SF) scores.

PCS and MCS calculated as an average before and after eight weeks of rehabilitation therapy were compared with a Romanian quality of life study comprising n=928 patients with different medical interventions - SF-36v2-RO (Mardare et al., 2019) to highlight the differences of this particular approach.

The international proposal for the PCS and MCS calculation process is based on the z-score determined for the first eight scales relative to the mean of the general population. Since there is no Romanian norm, the study on the American norm was selected as a benchmark to determine the z-score for each subject by subtracting the individual scale obtained by the mean of the group according to age and then dividing by the corresponding standard deviation. The Z-scores multiplied by the factor coefficient for the eight scales are summed to determine the PCS and MCS, multiplied by 10 and added to 50. Thus there is a linear transformation of the PCS and MCS physical and mental component summary scores into the T-score metric, which has a mean of 50 and a standard deviation of 10 for the general population (Laucis et al., 2015; Taft et al., 2001).

13.4. Evaluation criteria of the questionnaire

The evaluation criteria of the questionnaire reached the 8 mandatory evaluation points of a questionnaire. The eight elements for evaluating the instrumental applicability of the SF-36 instrument as appropriateness, acceptability, feasibility, validity, reliability, responsiveness, precision and interpretability are analyzed in accordance with clinimetric and psychometric principles (Fitzpatrick et al., 1998; Murgoci, 2023; Naci & Ioannidis, 2015).

The criteria were analyzed taking into account the sequence of their application (**Figure 13.1**)

- **Constructive criteria** recommending the application of the RAND SF-36 version 1 questionnaire – criterion no. 4 validity according to the Medical Outcomes Study n=2471 (Brazier et al., 1996, 1999; rand.org, 2022; Walters et al., 1999) and no. 7 accuracy (use of Likert scales with multiple answer options, minimum 2, maximum 6);
- **Technical-economic criteria** – criterion no. 2 acceptability, criterion no. 3 feasibility and criterion no. 8 interpretability;
- **Criteria that reflect the results** obtained following the application of the questionnaire – criterion no. 5 reliability and criterion no. 6 receptivity;
- **Criterion no. 1 appropriateness or suitability**, which answers whether the content of the questionnaire meets the main purpose of the study, namely the facilitation of ambulation.

TECHNICAL AND ECONOMIC	⇨	***2. ACCEPTABILITY***	***3. FEASIBILITY***	***8. INTERPRETABILITY***	
CONSTRUCTION	⇨	**4. VALIDITY**	**1. APPROPRIATENESS**		**7. PRECISION**
RESULT	⇔	***5. RELIABILITY***		***6. RESPONSIVENESS***	

Figure 13.1 The sequence of application of the SF-36 criteria [own contribution]

13.4.3. Analysis of the target criterion that responds to the main purpose of the study

→**Criterion no. 1 appropriateness or suitability** is answered if the content of the questionnaire meets the main purpose of the study, namely the facilitation of ambulation**.**.

Orthostatic postural stability is defining for the control ability of the central nervous system to maintain balance representing a relevant test to verify the objective of facilitating ambulation and implicitly the suitability of the applied quality of life questionnaire SF-36 to the main purpose of the study. The more stable the orthostatic position is, the less the body swings and the better the balance, the more stable the gait.

Description of the technique: at the end of the rehabilitation period, the stability test was applied, which consisted in maintaining the unipodal balance of the lower limb subject to analysis on the AmazFit body scale from the own office. According to **Table 13.102**, each patient is given a score by correlation with the Zepp Analyzer application according to their proprioception capacity..

Table 13.102 Postural stability – AmazFit – correlation with Zepp Analyzer

Score	Postural stability - interpretation
0-20	low
20-40	minimum
40-60	normal
60-80	very good
80-100	excellent

The results of the stability score are shown in Table 13.104 for the control group after performing the proprioception and balance test.

Table 13.103 Stability score results - control group

Subject	VAS T2	Dif VAM T2	BA T2	BORG T2	BM T2	PCS T2 Z	MCS T2 Z	Stability score	Interpretation of stability
1.A.M.	2.00	32	115	2	5.00	50.25	59.31	72	very good
2.B.A.	1.00	36	52	3	5.00	44.56	50.10	65	very good
3.B.I.	2.00	5	62	2	5.00	49.99	75.93	55	normal
4.C.N.	1.00	15	85	4	5.00	53.97	65.23	59	normal
5.D.N.	1.00	17	98	2	5.00	47.53	44.76	71	very good
6.G.L.	0.00	32	49	3	4.00	47.19	51.60	49	normal
7.G.V.	2.00	9	66	3	5.00	42.21	41.24	81	excellent
8.M.T.	3.00	36	80	4	4.00	49.77	54.67	67	very good
9.N.A.	2.00	42	38	4	3.00	27.41	30.27	42	normal
10.O.P.	1.00	19	105	3	5.00	51.04	53.88	48	normal
11.P.M.	1.00	29	82	3	5.00	51.64	58.45	79	very good
12.V.I.	1.00	19	115	3	5.00	59.76	60.25	85	excellent

The descriptive statistics applied to the stability score obtained after testing the control group shows a mean of 64.42±13.970, a median of 66.00, with a minimum of 42 and a maximum of 85. **(Table 13.104, Figure 13.9).**

Table 13.104 Descriptive statistics - stability score - control group

Control group indicators		Stability score
N	Valid	12
	Missing	0
Mean		**64.42**
Median		**66.00**
Standard deviation		13.970
Minimum		**42**
Maximum		**85**
Percentile	25	50.50
	50	66.00
	75	77.25

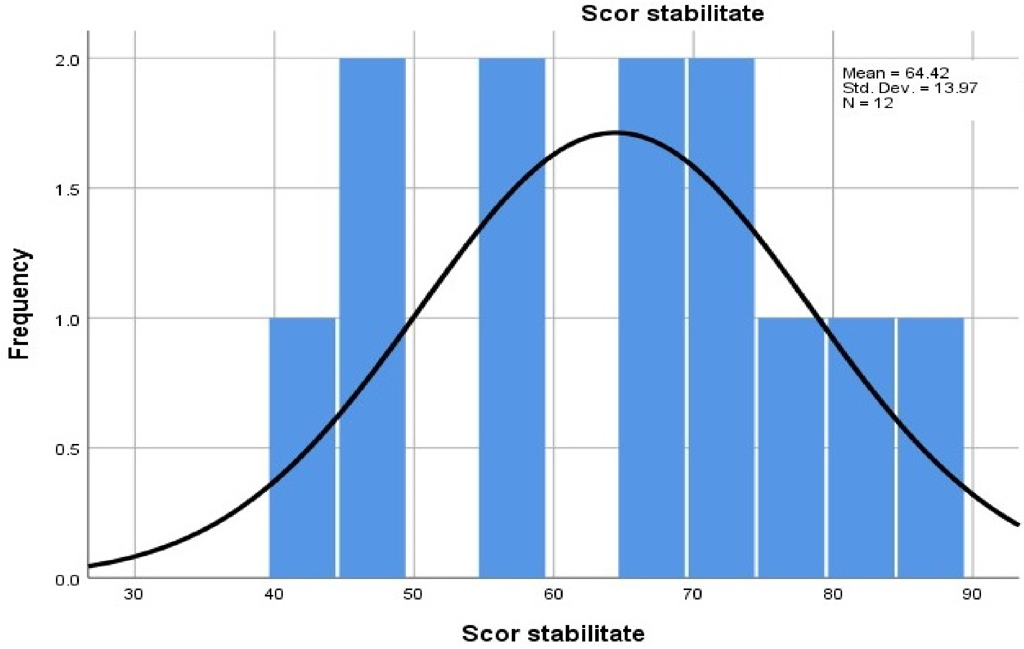


Figure 13.9 Frequency analysis - stability score - control group

From the total of 12 patients belonging to the control group, two recorded excellent values (16.7%), five very good (41.7%) and five patients normal values (41.7%) for the stability score (**Table 13.105**).

Table 13.105 Stability score interpretation – control group

Interpretation of stability score Control group		Frequency	Percent	Cumulative percentage
Validity	excellent	2	16.7	16.7
	very good	5	41.7	58.3
	normal	5	41.7	100.0
	Total	12	100.0	

The results of the stability score are shown in **Table 13.106** for the experimental group after performing the proprioception and balance test.

Table 13.106 Stability score results - experimental group

Subiecti	VAS T2	Dif VAM T2	BA T2	BORG T2	BM T2	PCS T2 Z	MCS T2 Z	Stability score	Interpretation of stability
1.A.J.	1.00	11	82	2	5.00	52.84	60.21	65	very good
2.B.C .	1.00	31	37	3	5.00	56.01	54.93	55	very good
3.C.R.	1.00	7	125	3	5.00	40.03	59.08	82	excellent
4.D.E.	0.00	41	56	3	4.00	50.38	36.89	49	normal
5.I.A.	2.00	5	85	3	5.00	46.14	58.45	63	very good
6.I.D.	2.00	46	75	4	5.00	27.19	31.11	42	normal
7.I.N.	0.00	10	115	2	5.00	69.83	75.38	86	excellent
8.N.C.	0.00	23	109	2	5.00	74.01	71.45	81	excellent
9.P.C.	2.00	12	105	4	5.00	40.03	59.08	75	very good
10.P.E.	0.00	7	65	2	5.00	65.71	58.45	83	excellent
11.R.D.	1.00	36	35	4	4.00	29.12	31.43	52	normal
12.S.C.	0.00	4	66	2	5.00	69.47	66.99	62	very good

The descriptive statistics applied to the stability score obtained after testing the experimental group shows a mean of 66.25±14.949, a median of 64.00, with a minimum of 42 and a maximum of 86 **(Table 13.107, Figure 13.10).**

Table 13.107 Descriptive statistics - stability score - experimental group

Experiment group indicators		Stability score
N	Validity	12
	Missing	0
Mean		66.25
Median		64.00
Standard deviation		14.949
Minimum		42
Maximum		86
Percentiles	25	52.75
	50	64.00
	75	81.75

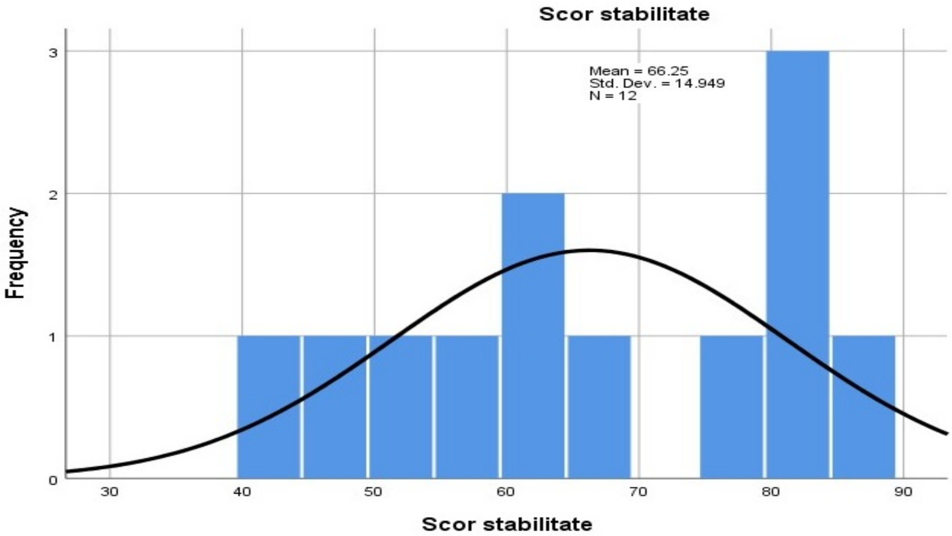


Figure 13.10 Frequency analysis - stability score - experimental group

From the total of 12 patients belonging to the experimental group, four recorded excellent values (33.3%), five very good (41.7%) and three patients normal values (25%) on the stability score (**Table 13.108**).

Table 13.108 Stability score interpretation – experimental group

Interpretation of stability score experimental group		Frequency	Percent	Cumulative percentage
Validity	excellent	4	33.3	33.3
	very good	5	41.7	75.0
	normal	3	25.0	100.0
	Total	12	100.0	

In order to compare the efficiency of the two standard and proposed rehabilitation programs, the multiple regression analysis - ordinary least squares (OLS) was applied - the least squares method that responds to the minimum estimation error for determining the coefficients of the linear regression equations that describe the relationship between several quantitative independent variables and a dependent variable.

The dependent variable is the stability score (proprioception and balance test) obtained after eight weeks of rehabilitation (T2) and as dependent variables were considered the joint balance (BA T2), muscle balance (BM T2), the difference in muscle imbalances between the lower limbs (Dif VAM T2) and the summarized physical components calculated based on the Z score according to the quality of life questionnaire SF-36 version 1. **(Table 13.109)**

Table 13.109 Multiple regression analysis - control/experimental group

Variables Introduced/ Eliminated [a]			
Model	Variables Introduced	Removed variables	Metod
1	Dif VAM T2, BA T2, PCS T2 Z, BM T2[b]	.	Enter
a. Dependent variable: Stability score			
b. All defined variables entered.			

The results of the multiple regression analysis for the control group did not demonstrate interdependence between the independent variables considered as predictors of estimation, namely the value of the differences in muscle imbalances, the joint and muscle balance values, the summarized physical components. Adjusted R2 = .049, p=.411(p>.05), according to the tables **Table 13.110, Table 13.111, Table 13.112.**

Table 13.110 Calculation of R^2 – control group

Summary of analysis – control group				
Model	R	R^2	R^2 ajustat	Estimated standard error
1	.628[a]	.395	.049	13.626
a. Predictors: (Constant), Dif VAM T2, BA T2, PCS T2 Z, BM T2				

Table 13.111 ANOVA – control group

ANOVA[a] - control group						
Model		Sum of squares	df	Mean of squares	F	Sig.
1	Regression	847.288	4	211.822	1.141	.411[b]
	Residual	1299.628	7	185.661		
	Total	2146.917	11			
a. Dependent variable: Stability score						
b. Predictors: (Constant), Dif VAM T2, BA T2, PCS T2 Z, BM T2						

Table 13.112 Beta coefficients - control group

Coefficients[a] – control group						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-7.006	49.996		-.140	.892
	BA T2	.121	.235	.226	.517	.621
	BM T2	11.966	10.963	.558	1.091	.311
	PCS T2 Z	.013	.878	.008	.015	.988
	Dif VAM T2	.221	.465	.186	.475	.649
a. Dependent variable: Stability score						

The results of the multiple regression analysis for the experimental group demonstrated interdependence between the independent variables considered as predictors of estimation, namely the value of the differences in muscle imbalances, the joint and muscle balance values, the summarized physical components. Adjusted R^2 = .671, p=.016(p<.05), according to the tables **Table 13.113, Table 13.114**.

Table 13.113 Calculation of R^2 – experimental group

Summary of the analysis - experimental group				
Model	R	R^2	R^2 ajustat	Estimated standard error
1	.889[a]	.790	.671	8.578
a. Predictors: (Constant), PCS T2 Z, BA T2, BM T2, Dif VAM T2				

Table 13.114 ANOVA – experimental group

ANOVA[a] – experimental group						
Model		Sum of squares	df	Mean of squares	F	Sig.
1	Regression	1943.192	4	485.798	6.602	.016[b]
	Residual	515.058	7	73.580		
	Total	2458.250	11			
a. Dependent variable: Stability score						
b. Predictori: (Constant), Dif VAM T2, BA T2, PCS T2 Z, BM T2						

Table 13.115 Beta coefficients - experimental group

Coefficients[a] – grupul de experiment						
Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	62.960	42.811		1.471	.185
	Dif VAM T2	-.394	.234	-.402	-1.684	.136
	BA T2	.266	.109	.527	2.439	.045
	BM T2	-5.404	8.801	-.141	-.614	.559
	PCS T2 Z	.307	.186	.326	1.647	.144
a. Dependent variable: Stability score						

The values of the muscle and joint balance depending on the injured joint and the difference in value between the muscle imbalances of the lower limbs and the summarized physical components synergistically influence the result of the stability score in the property of 67.1% adjusted effect, 79% unadjusted, respectively R=88.9%.

The joint balance has a beta coefficient of .527 with a statistical significance of .045 ($p<.05$) proving that the simultaneous rhythmic movement involving the triple flexion/extension chain with the help of the static horizontal bicycle led to the validation of the result in favor of the proposed program which used the horizontal static pedal device- **Table 13.115**, after the intercorrelation of all statistical analysis models performed.

CHAPTER 14. CONCLUSIONS PART III

The conclusions were grouped according to the measured parameters and the statistical interpretations

14.1 General characteristics

14.1.1. The control group and the experimental group each included 12 subjects with the following general characteristics**:**

→ The control group

- average age 51.42±14.829, average weight 72.73±18.010, average height 1.71±.076, IMC - body mass index (BMI) 24.97±6.334;

- according to age 30-39 years – 25% (three subjects), age group 40-49 years – 33.3% (four subjects), age group 50-69 years – 25% (three subjects) and age group >70 years – 16.7% (two subjects);

- depending on gender, it includes five women - 41.7% (one subject belonging to the 30-39 years old group, two subjects belonging to the 40-49 years old group and two subjects belonging to the 50-69 years old age group) and seven men - 58.3% (two subjects belonging to the 30-39 years old group, two subjects belonging to the 40-49 years old group, one subject belonging to the 50-69 years old group and two subjects > 70 years old);

- The BMI of the control group: 33% of the subjects have a normal weight (one subject in each age group), 25% are overweight (two subjects in the 40-49 age group and one subject in the 50-69 age group) , 25% obese (one subject each belonging to the groups 40-49 years, 50-69 years and >70 years) and 17% underweight (2 subjects belonging to the age group 30-39 years);

→ The experimental group

- average age 49.75±14.156, average weight 79.83±16.331, average height 1.69±.092, body mass index (BMI) 27.95±5.633;

- according to age 30-39 years – 25% (three subjects), age group 40-49 years – 25% (three subjects), age group 50-69 years – 33.3% (four subjects) and age group >70 years – 16.7% (two subjects);

- depending on gender, it includes six women - 50% (one subject each belonging to the 30-39 years old group, respectively the 40-49 years old group and two subjects each belonging to the 50-69 years old and >70 years old age group) and six men - 50% (two subjects each belonging to the 30-39 year old group, the 40-49 year old group and the 50-69 year old group);

- BMI of the experimental group: 33% of the subjects have normal weight (three subjects belonging to the age group 30-39 years and one subject aged 40-49 years), 42% are overweight (one subject belonging to the age group 40-49 years, two subjects belonging to the 50-69 years group and two subjects aged > 70 years), 25% obese (one subject belonging to the 40-49 years group and two subjects belonging to the 50-69 years group).

Comparative situation IMC (BMI) control/experiment group denotes a BMI = 24.97±6.33 for the control group compared to BMI =27.95±5.63 for the experiment group **- Figure 14.1.**

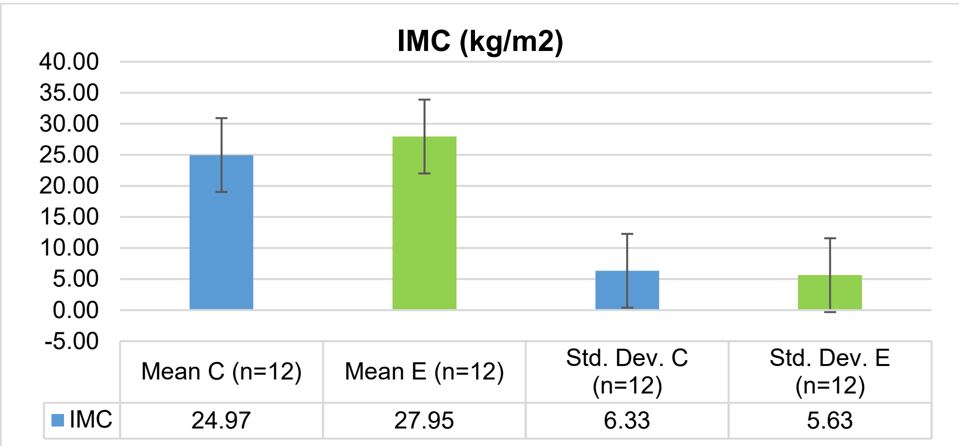


Figure 14.1 Comparative situation of IMC control/experimental group

14.1.2 Spearman correlations at the level of the control group and the experimental group

The Spearman correlations at the level of the control group highlighted a strong positive association between the female gender (F) and the FFMI Intermediate somatotype (r= 1, p<.000, CI = 99%)

The Spearman correlations (r=1, p<.000, CI =99%) at the level of the experimental group highlight the fact that:

- the female gender correlates strongly negatively with the solid and thin FFMI somatotype;
- the FMI adipose somatotype correlates strongly negatively with the solid FFMI somatotype;
- the solid FFMI somatotype correlates strongly negatively with the intermediate FFMI somatotype.

14.1.3 Assessment of somatotype

The control group includes 12 patients who were classified according to Table 24 and Figure 13 according to:

- representation of **adipose tissue** by age groups in **adipose**, **total 58%** of which 25% (40-49 years), respectively 17% (50-69 years, > 70 years), **intermediate total 17%** of which 8% (40- 49 years, 50-69 years) and **25% weak** (30-39 years);
- the representation of **non-adipose tissue** by age groups in **solid 8%** (>70 years), respectively **intermediate total 67%** of which 8% (30-39 years), 25% (40-49 years, 50-69 years), 8% (>70 years) and total **thin 25%** of which 17% (30-39 years), 8% (40-49 years).

The experimental group includes 12 patients from which:

- representation of **adipose tissue** by age group in **total fat 92%** of which 17% (30-39 years), 25% (40-49 years), 33% (50-69 years), respectively 17% (> 70 years) and **intermediate 8%** (30-39 years)
- representation of **non-adipose tissue** by age groups in **solid total 25%** of which 17% (40-49 years), 8% (50-69 years), respectively **intermediate, total 50%** of which 8% (30-39 years , 40-49 years, >70 years), 25% (50-69 years) and **thin, total 25%** of which 17% (30-39 years), 8% (>70 years).

For the control group, muscle imbalances were tested to achieve comparative statistics with the experimental group and to determine the effectiveness of the physical therapy program applied according to the stability risk profile: 6 patients - program B, 6 patients - program C.

For the experimental group composed of 12 patients, it was proposed in the physical therapy program for 2 patients pedaling type A, for 5 patients pedaling type B and for 5 patients pedaling type C.

The T-test applied to the analyzed somatotypes were statistically relevant for both groups. The ANOVA according to the body mass index (dependent variable) in the control group and the experimental group showed a p= 0.006 (p<0.05), the effect size = 51.9%, that is, in 51.9% of the total subjects, the weight of adipose tissue significantly influences the value BMI. The pedaling program A (27 minutes) – 2 subjects, B (31 minutes) – five subjects and C (35 minutes) – five subjects was applied to the experimental group, in correlation with the somatotype of each patient and the associated risk.

No sarcopenia was identified in the patients from the final research based on bio-impedance according to the age groups and gender, instead, the adipose somatype represents an important risk factor for all the analyzed age groups.

14.2 Motor rehabilitation

14.2.1 Assessment of pain

The T-test for paired samples allows the evaluation of the significance of the variation of the VAS, in the same subjects, in two different situations: before and after performing the rehabilitation program

The answer to the question of whether the standard rehabilitation program was statistically relevant is yes. The observed difference between the averages is 4,167. Since the value of the T test is 17.289 for the p < .000 threshold, the difference 4.167 between the averages of the VAS variables pretest and posttest is statistically significant - **Figure 14.2**.

The answer to the question of whether the proposed rehabilitation program was statistically relevant is affirmative. The observed difference between the means is 4.5. Since the value of the T test is 17.234 for the p < .000 threshold, the difference of 4.5 between the averages of the pretest and posttest VAS variables is statistically significant - **Figure 14.2**.

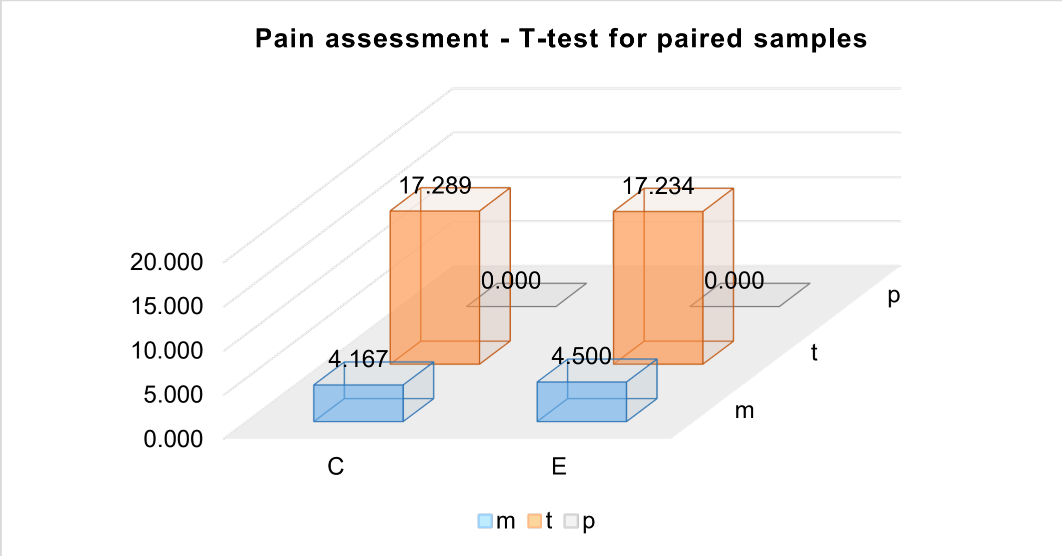


Figure 14.2 Pain assessment - T-test for paired samples C/E- T0/T2

Bar analysis after eight weeks of rehabilitation reveals

- 74.5% decrease in pain perception threshold for the control group using the standard rehabilitation program;
- 84.4% decrease in pain perception threshold for the experimental group using the proposed rehabilitation program.

The parametric test z (t) Pain perception analysis (VAS) shows a significant statistical significance for the experimental group and the control group p<0.002, Z(C) = -3.100, Z(E) = -3.108

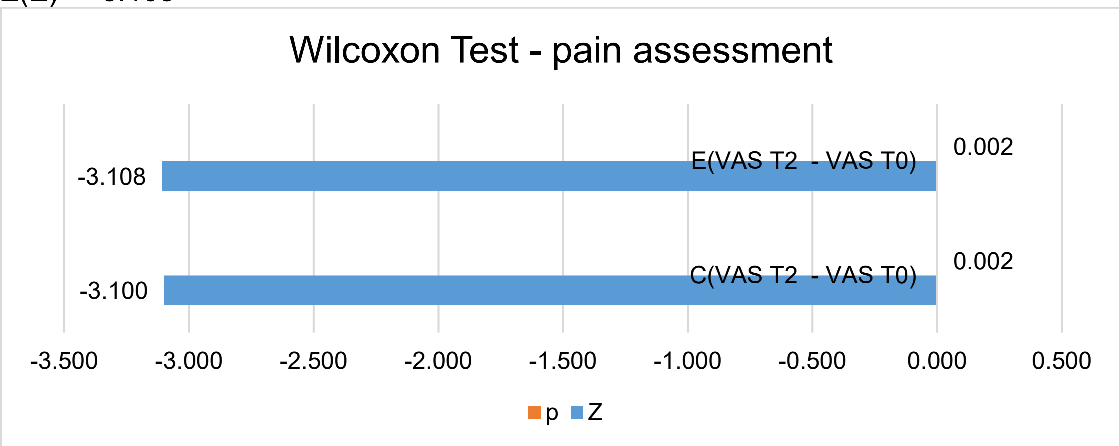


Figure 14.3 Wilcoxon Test - pain assessment C/E- T0/T2

The sign test is statistically significant for the control and experimental group p<.000.

14.2.2 Joint balance sheet

Out of the total of 12 patients – 5 patients had damage to the ankle joint, 5 to the knee joint, 2 damage to the coxo-femoral joint for both control and experimental groups to be able to compare the results from a statistical point of view.

The analysis with control bars identified a 64.58% increase in the average articular amplitude related to the control group (from 48 degrees to 79 degrees) and by 122% to the experimental group (from 36 degrees to 80 degrees) as a result of the program proposed.

T-test for dependent paired samples

The standard physical therapy program has an effect on joint mobility. Since the value of the T test is t=-8.731 for the p = .000 threshold, the difference of -31.083 between the averages of the BA T0 and BA T2 variables is statistically significant - **Figure 14.4.**

The physical therapy program proposed has an effect on joint mobility. Since the value of the T test is t=-6.514 for the threshold p = .000, the difference of -43.583 between the averages of the BA T0 and BA T2 variables is statistically significant - **Figure 14.4.**

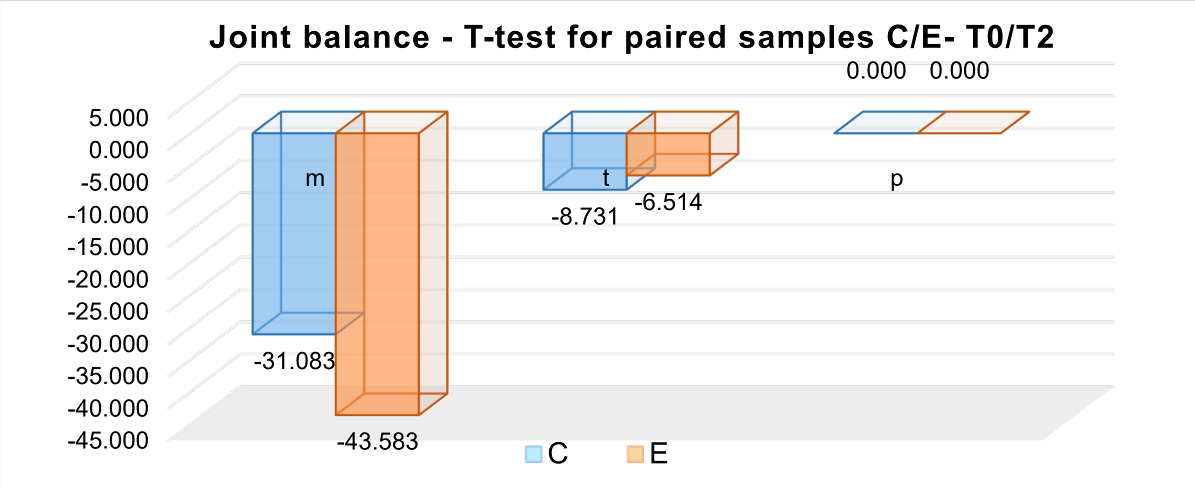


Figure 14.4 Joint balance - T-test for paired samples C/E- T0/T2

Wilcoxon test for two paired samples for joint balance (BA)

The Wilcoxon test applied to the control and experimental groups after the standard physiotherapy program, depending on the amplitude of the injured joint, demonstrates statistical relevance p=.002 (<0.05), Z(C) = -3.065, Z(E) = -3.059 – **Figure 14.5.**

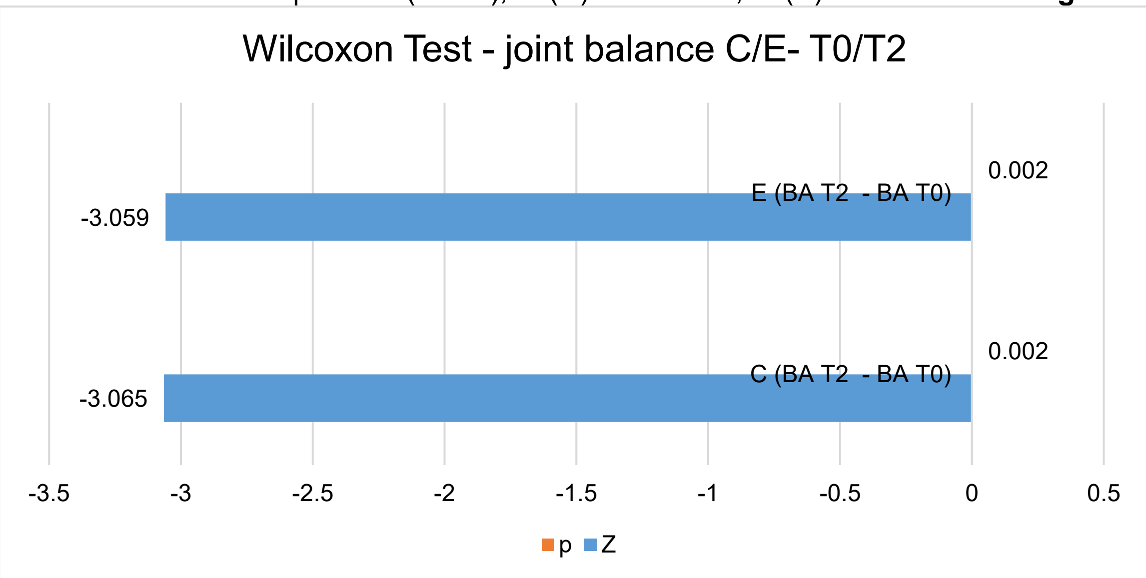


Figure 14.5 Wilcoxon Test - joint balance C/E- T0/T2

The sign test is statistically significant for the control and experimental group p<.000.

14.2.3 Muscle balance

The muscle balance was evaluated at the level of the affected muscle groups according to the basic pathology of each patient by analyzing the differences in average analog values (VAM) between the two lower limbs and the muscle strength in MRC units.

Following the comparative segmental analysis between the two programs, the effectiveness in correcting total muscle imbalances was 75% with an effect at the knee level of 55.70%, the coxo-femoral joint at 15.39% and the ankle at 3.91%. Improvement in ankle muscle strength was 16.22% in MRC units**.**

Analysis of muscle imbalances with control bars – analog values transmitted by sensors reveals:

- in the control group an average of 54 average analogue values in absolute value, which was reduced to 24 average analogue values after the standard physiotherapy program, the difference being 30 units.

- in the experimental group, an average of 58 average analog values in absolute value, which was reduced to 19 average analog values in absolute value after the proposed physical therapy program, the difference being 39 units.

Therefore, there was a 30% = [(39-30)/30]* 100 reduction in muscle imbalances associated with the lower limbs with the proposed physical therapy program compared to the standard program.

The analysis of muscle balance in MRC units reveals:

- in the control group an average of 3.25 MRC, which improved to 4.67 MRC after the standard physiotherapy program, the difference being 1.42 MRC units.

- in the experimental group, an average of 3.33 MRC, which improved to 4.83 MRC after the proposed physical therapy program, the difference being 1.5 units.

Therefore, there was a 5.64% = [(1.5-1.42)/1.42]* 100 improvement in muscle imbalances associated with the lower limbs with the proposed physical therapy program compared to the standard program.

As a result of the application of the rehabilitation program that uses the static horizontal bicycle, there is a considerable improvement in muscle imbalances related to the triple flexion chain by 30% higher than the standard program, the strength tested at the affected muscle level being recovered by 5.64% more efficiently with the stationary pedal system.

Paired-samples T-test applied to muscle imbalances (DM) expressed as the difference in mean analog values between the intact and the affected lower limb

- The standard physical therapy program has an effect on muscle imbalances. The observed difference between the averages is 29.5. Since the value of the T test is t=7.899 for the threshold p = .000, the difference of 29.5 between the averages of the VAM T0 and VAM T2 variables is statistically significant **- Figure 14.6.**

- The proposed physical therapy program has an effect on muscle imbalances. The observed difference between the averages is 38,417. Since the value of the T test is t=9.134 for the threshold p < 0.05 (.000), the difference of 38.417 between the averages of the VAM T0 and VAM T2 variables is statistically significant - **Figure 14.6.**

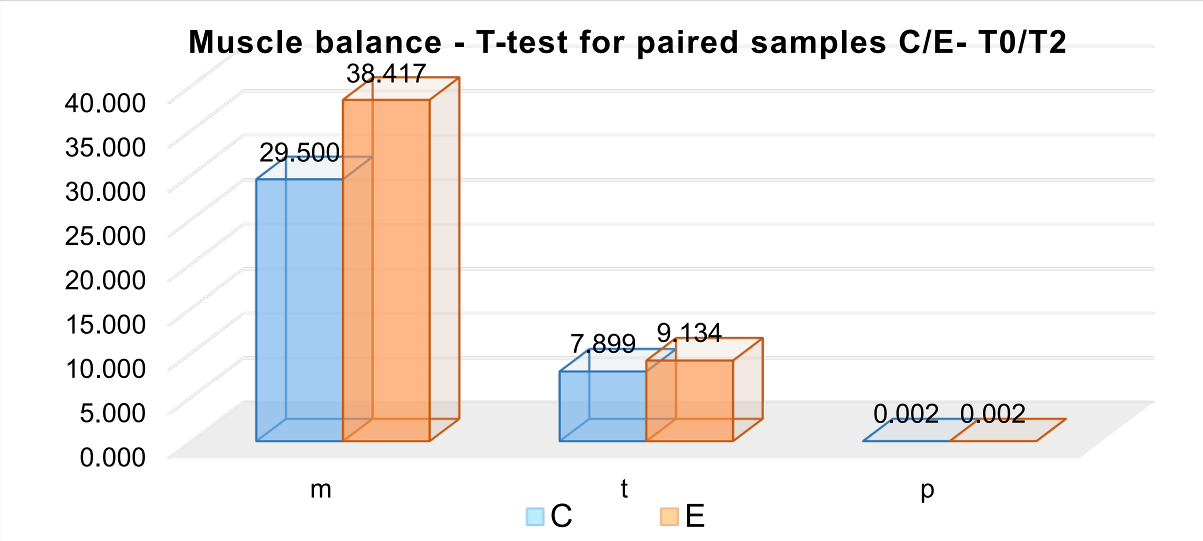


Figure 14.6 Muscle balance - T-test for paired samples C/E- T0/T2

Wilcoxon test for two paired samples

The Wilcoxon test applied to the control and experimental groups after performing the standard physiotherapy program, depending on the recorded correction of muscle imbalance, demonstrates statistical relevance p=.002 (<0.05), Z(C) = -3.062, Z(E) = -3.066.

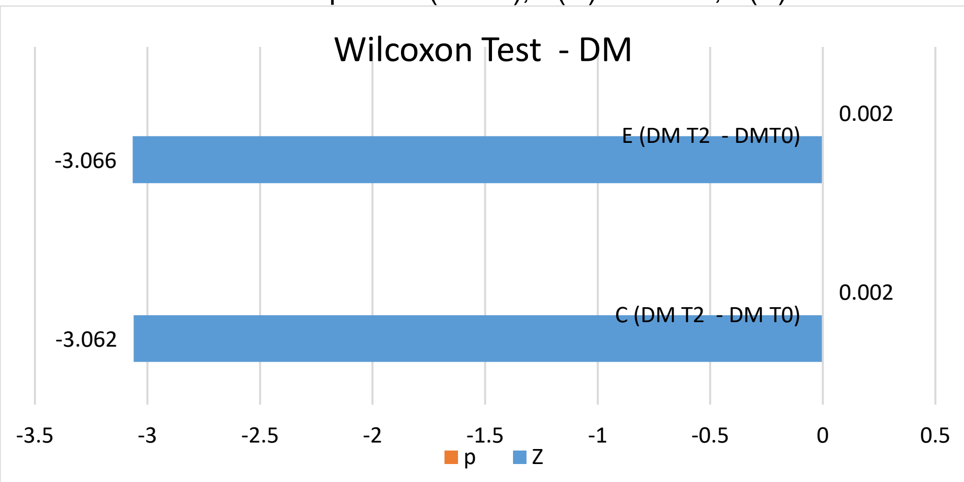


Figure 14.7 Muscle imbalances - Wilcoxon C/E- T0/T2 test

Testul semnelor este semnificativ statistic pentru grupul de control şi experiment p<.000.

14.2.4 Heart rate monitoring

Descriptive statistics showed that the measured values (mean/median) during the rehabilitation programs were below the target heart rate values calculated using Karvonen's formula according to the rehabilitation phases for both tested groups, maintaining the effort at an aerobic level.

Testing the patients' tolerance to effort by testing the adaptation of the autonomic nervous system was carried out with the help of the chronotropic deficit. On average, the chronotropic deficit was reduced by 12.01% in the experimental group compared to the control group by 10.86%.

The regression equation related to the heart rate (y=0.9476x+129.26) for the experimental group according to the maximum heart rate respects the correlation for 14.03% (R2=.0143) of the subjects. This can also be explained by the fact that the horizontal exercise bike addresses the triple flexion/extension chain, which involves an organized, concurrent, simultaneous and rhythmic movement compared to 1.22% (R2=0.0122) of the subjects belonging to the standard group in which each physical therapy program it addresses with predilection the injured joint.

14.2.5 Measurement of perceived exertion

Rehabilitation programs maintained on a scale of 0 to 10 a perceived level of moderate effort with:

- an average of 3.58 Borg –T1 and 3 Borg – T2 for the control group
- an average of 3.67 Borg – T1 and 2.83 Borg – T2 for the experimental group.

Adaptation to exercise was easier with the rehabilitation program involving the static horizontal bike by 41.23% (reporting 22.83% versus 16.20%):

- 16.20% improvement in exercise tolerance for the control group;
- 22.88% improvement in exercise tolerance for the experimental group.

The final conclusion is that the proposed physical therapy program involving the static horizontal pedal board has proven its effectiveness according to the statistical tests applied to the motor rehabilitation of the lower limbs.

14.3 Quality of life

SF36 questionnaire application conclusions emerge from the cluster analysis of results at the level of the physical and mental components summarized with the mention that all the health dimensions evaluated recorded statistically significant values for both groups.

Following the standard and proposed rehabilitation program applied at the level of the control and experimental groups, the following results were obtained at the level of the quality of life at the intragroup and intergroup level, as well as compared to the norm of the general population.

⇨Intergroup level

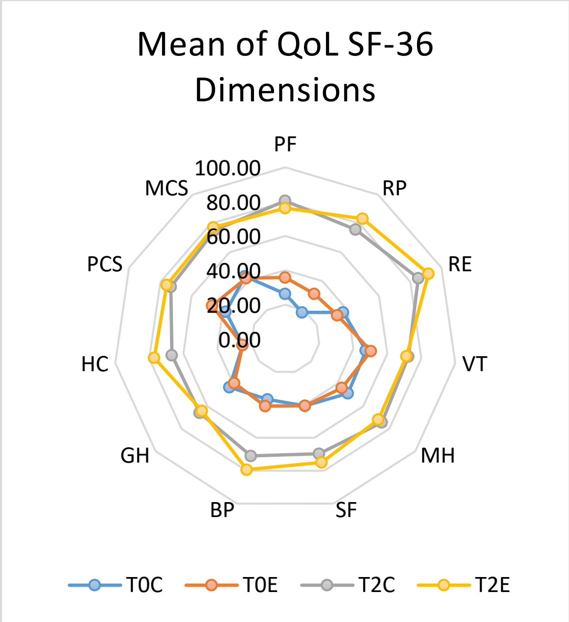
- for the physical components summarized at the end of the eight weeks of physical therapy compared to the initial values, an increase of 7.91% of the experimental group (51.73) compared to the standard (47.94);
- for the mental components summarized at the end of the eight weeks of physical therapy compared to the initial values, an increase of 2.75% of the experimental group (55.29) compared to the standard (53.81).

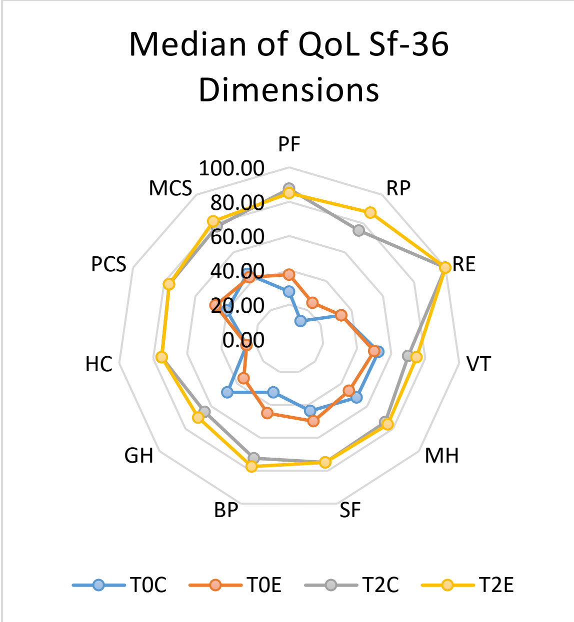
⇨ Normative level

- the control group - minus 4.12% up to the value of 50 for the summarized physical components (47.94) and 7.62% increase above the value of 50 for the summarized mental components (53.81);
- the experimental group - increase of 3.46% above the value of 50 for the summarized physical components (51.73) and of 10.58% above the value of 50 for the summarized mental components (55.29).

The synoptic graphic analysis shows the mean and median of the scales of health dimensions as well as of the summarized physical and mental components demonstrating positive results for the proposed rehabilitation program that used a static horizontal pedal board - **Table 14.1**.

Table 14.1 QoL assessment T0/T2 for each scale (Appendix No. 5), mean and median values





Mean	T0C	T0E	T2C	T2E
PF	26.25	35.83	80.42	76.25
RP	18.33	31.25	75.83	83.33
RE	36.98	33.32	85.12	91.68
VT	47.50	50.42	72.50	71.25
MH	48.33	43.67	74.33	71.67
SF	40.63	40.63	69.79	75.00
BP	36.67	40.83	71.04	79.38
GH	42.92	39.17	65.83	64.17
HC	25.00	25.00	66.67	77.08
PCS	38.07	46.82	73.28	75.78
MCS	43.36	42.01	75.44	77.40

Median	T0C	T0E	T2C	T2E
PF	27.50	37.50	87.50	85.00
RP	12.50	25.00	75.00	87.50
RE	33.30	33.30	100.00	100.00
VT	52.50	50.00	70.00	75.00
MH	52.00	46.00	74.00	76.00
SF	43.75	50.00	75.00	75.00
BP	32.50	45.00	72.50	77.50
GH	47.50	35.00	65.00	70.00
HC	25.00	25.00	75.00	75.00
PCS	40.00	47.19	76.88	76.88
MCS	45.01	42.70	78.00	81.63

The applied questionnaire was analyzed interdependently with the functional results being relevant for the program that included a static horizontal pedal rack - **Figure 14.8**.

<table>
<tr><td colspan="3">Conclusions of the statistical evaluation of the SF-36 V1 questionnaire - control group - T2 versus T0</td></tr>
<tr><td colspan="3">n=12, 5F- 41.7%, 7B - 58.3% - control group, n=12, 6F- 50%, 6B-50% - experimental group</td></tr>
<tr><td colspan="3">Control group - 3 subjects (25%) - 30-39 years, 4 subjects (33.3%) - 40-49 years, 3 subjects (25%) - 50-69 years, 2 subjects (16.7%) > 70 years
Experimental group - 3 subjects (25%) 30-39 years old, 3 subjects (25%) 40-49 years old, 4 subjects (33.3%) 50-69 years old, 2 subjects (16.7%) > 70 years old</td></tr>
<tr><td colspan="3">Rehabilitation intervention: eight weeks standard/proposed program 50 min, frequency 3 times/week</td></tr>
<tr><td colspan="3">Evaluation KIT: RAND 36-Item Health Survey 1.0</td></tr>
<tr><td colspan="3">Constructive criteria</td></tr>
<tr><td>Acceptability
100% response rate
Romanian version (New England Medical Center)
Average questionnaire completion time = 11 min 15 sec</td><td>Interpretability

Accredited translation into Romanian</td><td>Feasibility

SF-36 OrthoToolKit is licensed by Optum and available free online (Rand), 6 min completion time for the kit</td></tr>
<tr><td colspan="3">Technical-economic criteria</td></tr>
<tr><td>Validity
proven by the Medical Outcomes Study and specialized literature</td><td colspan="2">Precision
use Likert scales with multiple response options</td></tr>
</table>

Outcome criteria	
Reliability Intraclass correlation coefficient (ICC) evaluated with The Cronbach's Alpha coefficient has a maximum value of 1.000 (optimal value >0.9) for test-retest with two different observers for the control and experimental group at T0 and T2, using the two-way random effects model, p<.000 Consistency was determined with the Pearson correlation coefficient (r) at time T0 and T2 for each group separately.	**Responsiveness** Parametric tests T-Test, and nonparametric sign test, Wilcoxon (Z), p<.000 for the control/experimental group (PF, RP, RE, VT, SF, BP, MH, GH, HC) Determination of the effect size based on the z-score using the partial eta2 factor (η2) for the summarized physical and mental components - relevant effect (>.40) control group η2 = .664 PCS and .651 MCS experimental group η2 = .501 PCS and .537 MCS
Target criterion - objective	
Appropriateness Answer if the content of the questionnaire corresponds to the main purpose of the study, namely the facilitation of ambulation Application of postural orthostatic stability test (T2) The control group (12 patients) - the stability score recorded: 2 excellent values (16.7%), 5 very good values (41.7%) and 5 normal values (41.7%) The experimental group (12 patients) - the stability score registered: 4 excellent values (33.3%), 5 very good values (41.7%) and 3 normal values (25%) Multiple regression analysis - ordinary least squares (OLS) for comparing the efficiency of programs. The dependent variable is the stability score (proprioception and balance test) obtained after eight weeks of rehabilitation (T2) and as dependent variables were considered the joint balance (BA T2), muscle balance (BM T2), the difference in muscle imbalances between the lower limbs (Dif VAM T2) and the summarized physical components calculated based on the z-score The results of the multiple regression analysis for the experimental group showed interdependence between the independent variables considered as predictors of estimation adjusted R2 = .671, p=.016 (p<.05). The articular balance has a beta coefficient of .527 with a statistical significance of .045, proving that the simultaneous rhythmic movement involving the triple flexion chain with the help of the static horizontal bicycle led to the validation of the result in favor of the proposed program.	

Figure 14.8 Conclusions of the statistical evaluation of the SF-36 V1 questionnaire - control group - T2/T0

Multiple regression analysis - ordinary least squares (OLS) for comparing the effectiveness of rehabilitation programs used taking into account

The dependent variable is the stability score (proprioception and balance test) obtained after eight weeks of rehabilitation (T2) and the joint balance (BA T2), muscle balance (BM T2), the difference in muscle imbalances between the lower limbs were considered as dependent variables (Dif VAM T2) and the summarized physical components calculated based on the z-score. The results of the multiple regression analysis for the experimental group showed interdependence between the independent variables considered as predictors of estimation adjusted $R^2 = .671$, $p=.016$ ($p<.05$). The joint balance has a beta coefficient of .527 with a statistical significance of .045, proving that the simultaneous rhythmic movement involving the triple flexion/extension chain using the static horizontal bike led to the validation of the result in favor of the proposed program using the static horizontal pedals.

CHAPTER 15. GENERAL CONCLUSIONS, OWN CONTRIBUTIONS AND PERSPECTIVES

15.1 GENERAL CONCLUSIONS

15.1.1. Analysis of bibliographic sources

The analysis of bibliographic sources (references) in total of n = 198 by number and type includes 136 (68.69%) specialized articles and studies, 21 (10.61%) books, 34 (17.17%) internet sources and 7 (3.54%) articles "HeathCare Report" type - **Figure 15.1.**

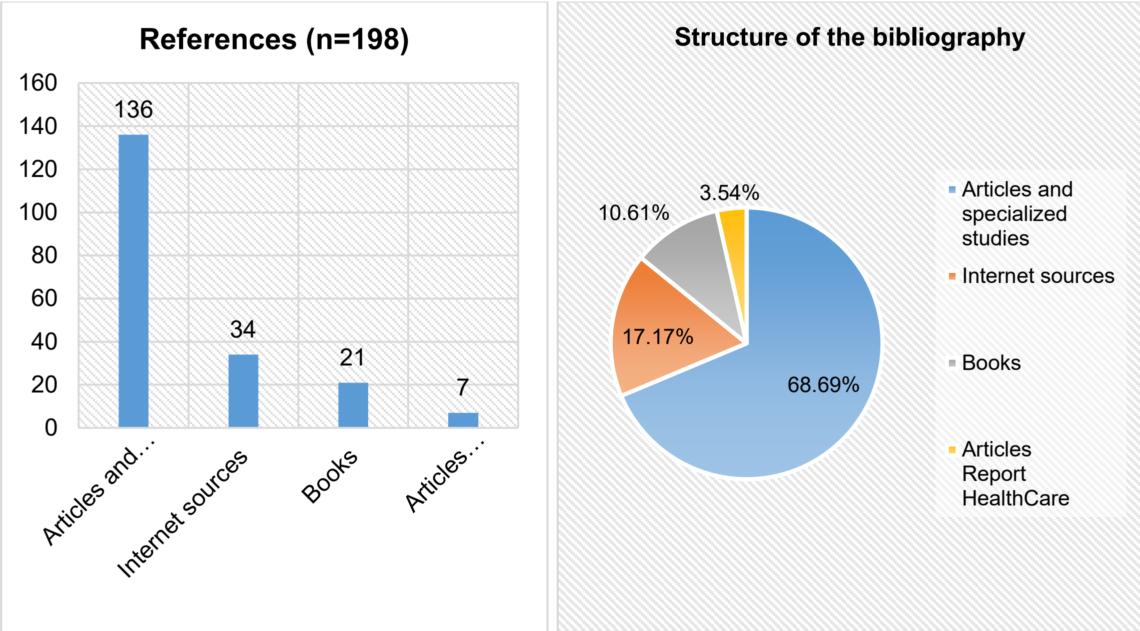
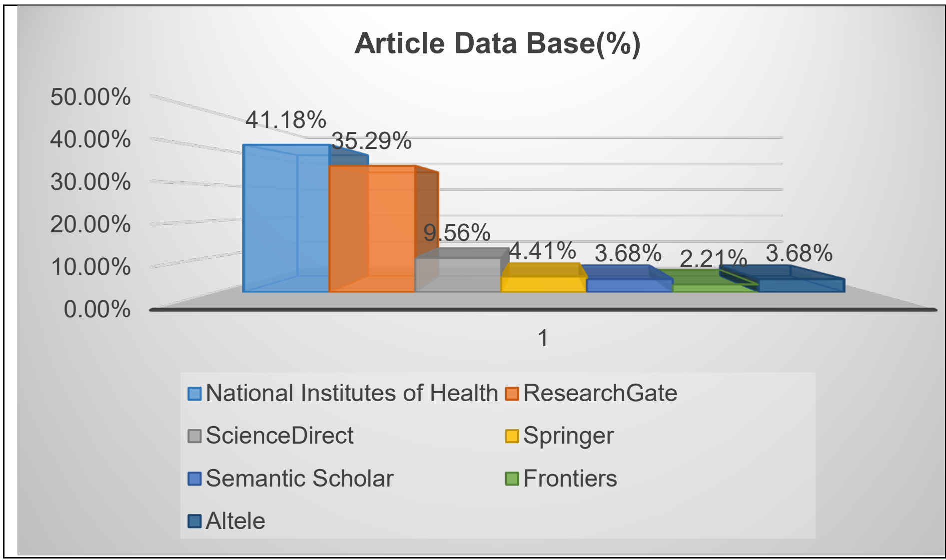


Figure 15.1 Structure of the bibliography [Own contribution]



Data Base	No
National Institutes of Health	**56**
ResearchGate	**48**
ScienceDirect	**13**
Springer	**6**
Semantic Scholar	**5**
Frontiers	**3**
Others	**5**

Figure 15.2 Database related to specialized studies [Own contribution**]**

The specialized articles and studies concerned databases: National Institutes of Health – 41.18% (56), ResearchGate – 35.29% (48), ScienceDirect – 9.56% (13), Springer -4.41% (6) and the remaining 9.56% (Semantic Scholar – 3.68%, Frontiers – 2.21%, others – 3.68%) – **Figure 15.2.**

15.1.2. Theoretical conclusions

1. In Romania, the need for rehabilitation services is increasing moderately according to the extended SWOT analysis of kinetotherapeutic means carried out in accordance with the local educational, medical and social assistance legislative measures and the increased rate of population aging.

2. Musculoskeletal rehabilitation equipment has a share of 70.43%, of which exercise equipment is also a part, the increase in global demand for physical therapy equipment being estimated at 7.8% per year until 2026, due to the high prevalence of degenerative diseases, traumas, the effects felt after COVID-19 and the increased number of the geriatric population combined with age-related maladjustments.

3. Pedaling exercise equipment is a rehabilitation favorite offering patients safety, independence, and psychological, emotional and physical benefits and is the central theme of the research carried out. The main objective of physical therapy is the rehabilitation of ambulation, an objective with motivational and economic-social implications that facilitates the resumption of personal activities, regaining independence, mobility and increasing the quality of life.

4. A rehabilitation treatment plan considers a comprehensive analysis of the patient in order to maximize the results of the applied recuperative program. Rehabilitation comprises three main phases, which address the acute inflammatory post-injury stage (phase I), the early tissue regeneration stage (phase II) and the tissue remodeling stage (phase III). Medical rehabilitation aims both at correcting deficiencies resulting from an injury and as a result of faulty movement patterns resulting from daily activities.

5. Motor rehabilitation related to the lower limbs using kinetotherapeutic equipment, respecting the principle of the kinetic chain, biomechanical deficit, muscle imbalances, functional exercise, periodization involves the aspects below - **Table 15.1:**

Table 15.1 Motor rehabilitation - methodological conclusions [Own contribution**]**

The scientific aspect	The evaluative aspect	The practical aspect	The correlative aspect
1. The articular stress/strain curve involves feedback adaptation with a control loop of the bone according to the maximum forces, a continuous process throughout life. 2. A minimum threshold of mechanical loading determines the increase in mineral-bone density according to Frost's theory, also called the theory of the minimum effective tension stimulus. 2. The ligament stress/strain curve establishes the failure zone from 8% elongation; in rehabilitation do not go beyond the elastic zone - 4-5%. 3. The speed of advancement of nerve regeneration is very variable, on average 1-4 mm/day, if in 18 months the regeneration was not done, the motor plate disappears and the rehabilitation becomes useless.	1. Joint/muscle balance 2. Redness occurs in 47% joint capsule and ligaments, 41% muscle fascia, 10% tendon, 2% skin. 3. Rehabilitation of gait in order of importance according to the global functional coefficient: ankle, knee hip- flexion. 4. The relative % contribution of each joint action to the total muscle power produced to generate maximum pedaling power is flexion 20%, extension = 80%. 6. Reflexes involved in medical rehabilitation: the H (Hoffmann) reflex and the tonic vibratory reflex.	**1**.Strength 3 separates patients with severe incapacity from those with normal capacity. 2. The participation of the muscles in pedaling is rendered synergistically at the level of both legs involved in pedaling and at the level of the agonist-antagonist force couple involved in coactivation. The quadriceps (RF, VL, VM) has a significant contribution in the power-extension phase (especially RF) and the semimembranosus (SM), the medial gastrocnemius (GM) and the biceps femoris (BF) in the power guard-flexion. In the withdrawal-flexion phase, an important role is played by the lateral gastrocnemius and the anterior tibialis together with the rectus femoris for extension 3. A simplified model of muscle coordination during pedaling consists of the synergy of the four functional muscle groups involved in pedaling. 4. Myokines derived from muscles are anti-inflammatory (IL-6), a minimum of 20 minutes of therapeutic exercises is recommended.	1. In pedaling, isotonic contraction is used, correlated with isometry. 2. The strategies of movement in pedaling involve: segmental analysis - determining the force of each segment of the MI, assessing the center of gravity for each segment of the body; the use of coactivation - simultaneous activation of the set of muscles that form the agonist-antagonist functional couple; 3. It is considered that the rehabilitation of a knee is not complete if we have not obtained an extensor/flexor ratio of 2/1 or the extensors are not 60% weaker compared to those of the opposite limb, achieved by pedaling in a ratio of 4: 1 (extension/flexion strength = 80/20) 4. The targeted heart rate rehabilitation zone (Karvonen formula) includes the maximum intensity range of 60-80% (moderate pace). 5.Target heart rate intensity is usually 40-60% (moderate) of heart rate reserve

15.1.3. Conclusions resulting from the preliminary experimental research and the final research

15.1.3.1. Conclusions related to the built static horizontal pedaling device and the proposed pedaling program

In the construction of the device, the prioritization of the objectives and the factors involved were taken into account: movement restrictions, precautions/contraindications, the stages of tissue healing as well as the treatment targets in accordance with the patient's social roles and his biological resources, the types of ailments that involve pedaling rehabilitation being multiple:

1. The horizontal pedal is intended for physiologically deconditioned patients, immobilized in bed at home, whose therapeutic window of intervention is critical for an adequate resumption of ambulation.

2. The ergonomic design of the construction of the horizontal pedal device correlating the optimal inter-pedal distance with the size of the step width while walking, respectively the self-selected QF factor of 14 cm, complied with the therapeutic medical indication for knee stability, reducing the risk of injury and increasing pedaling efficiency and the light aluminum profile structure with four lateral stabilizers on the ground facilitates pedaling.

3. The pedaling system built with fixing the legs through two support bands, one at the level of the calcaneus and the other on the dorsal side of the legs, the load being represented by the own weight of the lower limbs, with resistance in the pedal can be considered a kinetic chain controlled system controlled. It involves the use of three joints in a rotating sagittal plane, with a consolidated balance reaction in long sitting.

4. The supine position facilitates the reduction of edema and inflammation by increasing venous return, especially in the first phase of rehabilitation.

5. Pressure sensors attached to the pedals transmit analog values in real time, each rehabilitation session can be recorded with Data Streamer Excel for later statistical interpretation. Arduino open-source software is easy to use and involves minimal costs.

6. The development of the rehabilitation exercise program took into account the combination of multiple factors to ensure aerobic conditioning, assessment of perceived effort, adherence to treatment, minimum energy expenditure, maintaining homeostasis, by introducing pauses and sequencing the rhythm of pedaling intensity to strengthen positive motivation and replacing the exhaustion stage from the general adaptation syndrome with eustress. Three types of programs were proposed depending on the risk profile associated with each patient, known or not with comorbidities so that the result is optimal. The time of each program (minimum 20 minutes) for the anti-inflammatory effect of physical exercises is as follows: program A (high risk) – 27 minutes, B (moderate risk) – 31 minutes, C (minimum risk) – 35 minutes. (Figure 15.3)

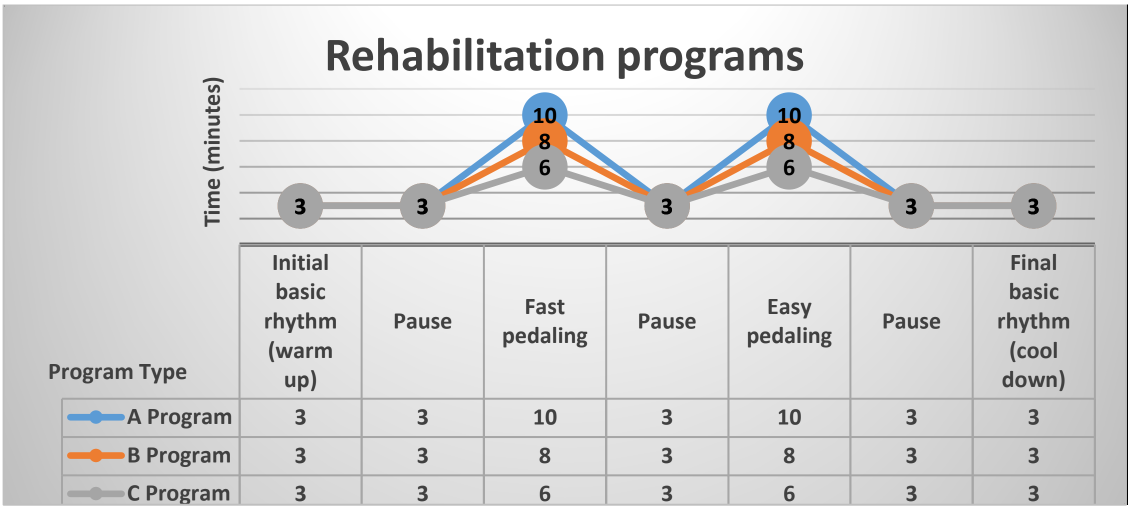


Figure 15.3 Proposed rehabilitation programs [Own contribution]

1. The values of the body composition determined by bio-impedance led to the appropriate risk stratification according to the statistical indices resulting from the personalized assessment of each patient. The risk assessment technique was supported by two published studies, namely the importance of body composition assessment in the rehabilitation process (MURGOCI, 2021) and the dosage of therapeutic exercise in accordance with the patients' risk diagram determined by bio-impedance (Murgoci, Mereuță, et al., 2022).

2. The use of the horizontal pedal board in vivo based on the informed consent of a patient with post-traumatic pathology of the lower limbs proved that the objectives regarding the facilitation of ambulation with the proposed rehabilitation program were achieved, the system being reliable and technically functional. Pedalboard testing was described in the published case study on the development of a program to facilitate walking with the help of a rehabilitation program that uses the horizontal bicycle designed and built to monitor the parameters of the kinetic chain (Murgoci, Mereuţă, et al., 2022).

15.1.3.2. Conclusions related to the research carried out - motor rehabilitation

The conclusion of the preliminary experimental research (N=10 subjects) is that the rehabilitation program that included the horizontal stationary bike achieved better results in terms of pain control and correction of muscle imbalances related to the lower limbs, with the mention that both programs recorded significant results statistically in terms of functionality. **(Table 15.2)**

Table 15.2 Motor rehabilitation - preliminary experimental research *[Own contribution]*

Control group n=5, 3B, 2F, mean age 58.67 ± 11.67, IMC (kg/m2) mean 28.17±4.50 2 subjects -40% 40-49 y, 1 subject - 20% 50-69 y, 2 subjects – 40% > 70 y						
Experimental group n=5, 2B, 3F, mean age 56.67 ± 12.14, IMC (kg/m2) mean 27.32±2.94 2 subjects -40% 40-49 y, 1 subject - 20% 50-69 y, 2 subjects – 40% > 70 y						
Monitored variables: perceived effort 3.6 Borg, RC < RCT (C/E)						
Evaluare concluzii	**VAS**		**Joint Balance**		**Muscle Imbalances**	
Teste statistice p<.05 CI 95%	C	E	C	E	C	E
Testul t perechi (p)	.004	.001	.042	.043	.003	.000
Wilcoxon test (p)	.041	.039	.000	.001	.043	.043
Indice corelaţie (r)					0.990	0.997

The final conclusion is that the proposed physical therapy program involving the static horizontal pedal board has proven its effectiveness according to the applied statistical tests, results also presented in the published comparative study that highlighted the effectiveness of the rehabilitation of the lower limbs using a static horizontal bicycle versus a therapeutic program (Murgoci, 2022a).

The final research conclusion (N=24 subjects) is that the rehabilitation program that included the horizontal stationary bike achieved better results in terms of pain control (84.4%) and correction of muscle imbalances related to the lower limbs (30%), efficacy analysis segmental 75% for the experimental group. Both programs recorded statistically significant results regarding joint balance **(Table 15.3).**

Tabelul 15.3 Reabilitarea motorie – cercetarea finală *[Contribuţie proprie]*

Control group n=12, 5F- 41.7%, 7B - 58.3%; **Experimental group** n=12, 6F- 50%, 6B - 50%						
Control group - 3 subjects (25%) - 30-39 y, 4 subjects (33.3%) - 40-49 y, 3 subjects (25%) - 50-69 y, 2 subjects (16.7%) > 70 y, **mean age 51.42 ± 14.83, IMC (kg/m^2) media 24.917±6.33**						
Experimental group - 3 **subjects** (25%) 30-39 y, 3 subiecţi (25%) 40-49 y, 4 subiecţi (33.3%) 50-69 y, 2 subiecţi (16.7%) > 70 y, **mean age 49.75 ± 14.16, IMC (kg/m^2) media 27.95±5.63**						
Monitored values: perceived effort 41.23⇩ E/C Borg, RC < RCT (C/E), DC η=14.3% E						
Segmental analysis E/C effectiveness în ↓ DM = 75% (G 55.70% , CF 15.39% , Glz 3.91%) şi ↑ Srength Glz = 16.22%						
Evaluare concluzii	**VAS**		**Joint Balance**		**Muscle Imbalances**	
Teste statistice p<.05 CI 95%	**C**	**E**	**C**	**E**	**C**	**E**
Testul t perechi (p)	.000	.000	.000	.000	.002	.002
Wilcoxon test (p)	.002	.002	.002	.002	.002	.002
Indice corelaţie (r)			.885	.658	.810	.832
Testul semnelor	.000	.000	.000	.000	.000	.000
Analiza cu bare de control	↓74.5%	↓84.4%				↑30% E/C

15.1.3.3. SWOT analysis related to the use of the static horizontal pedal system used in motor rehabilitation

Facilitation of walking is a basic goal of rehabilitation that has an impact on the quality of life of the individual, the health system and society. Exercise programs must be cost-effective, logical, and effective to achieve rapid improvements in motor function. The SWOT analysis related to the use of the static horizontal pedal system used identified the related strengths and opportunities according to **Table 15.4**

Table 15.4 SWOT analysis related to the use of the static horizontal pedal system used in motor rehabilitation, [own contribution] after personal study (Murgoci, 2022a)

Positives	
Strengths (+) - encouraging statistical results in terms of reducing pain, re-educating muscle imbalances, increasing joint amplitude, correlation with stability index and quality of life indicators; - promoting active movement along the entire kinetic chain of the lower limb; - addressability for deconditioned patients in the therapeutic window of opportunity for intervention; - rhythmic, alternative movement, reducing the biomechanical deficit; - good exercise tolerance tested also in post-Covid-19 patients, reduction of chronotropic deficit; - interactive interface for observing the way of pedaling thanks to the sensors attached to the pedals connected to the laptop, which leads to awareness of deficiencies and correction in real time; - the novelty element represented by the use of the velostat in a double layer of sensors, connected to the Arduino board, leads to an effective highlighting of muscle imbalances expressed in analog values.	**Opportunities (+)** - increased needs for ambulatory rehabilitation; - virtual reality enhanced pedaling systems are a challenge; - the rehabilitation of ambulation related to geriatric, post-stroke, post-trauma patients considerably reduces the expenses of the social and health system.
Negatives	
Weaknesses (-) - requires specialist assistance for monitoring perceived effort and heart rate; - patients must comply with the medication and the recommended hygienic-dietary regimen; - resource limitations regarding the equipment used and the adjacent personnel; - relatively limited number of patients in the study (total n=24, n=12 C/E).	**Threats (-)** - the services regarding the provision of exercise equipment for the lower limbs are partially supported by the social health insurance according to some rigorous criteria; -small number of accredited specialists in the field of physiotherapy at home.

15.1.3.4. Conclusions of the application of the SF-36 questionnaire - Quality of life

The measurement criteria of the RAND SF-36 V1 questionnaire (**Table 15.4**) were comprehensively analyzed in terms of appropriateness, acceptability, feasibility, validity, reliability, responsiveness, precision and interpretability. The analysis model was also developed and applied in the published study regarding the evaluation of the results of the quality of life after the motor rehabilitation of the lower limbs using a stationary horizontal bicycle (Murgoci, 2023).

Table 15.5 The measurement criteria of the RAND SF-36 V1 questionnaire, *according to (Murgoci, 2023)*

No.	Criteria	Details of the instrument used RAND SF-36 V1	Application
1	**Adecvare** Appropriateness	Content adapted to the objectives of the study	Main objective – facilitation of ambulation/gait rehabilitation
2	**Acceptabilitate** Acceptability	Acceptance rate from patients/family members	Response rates T0/T2 = 100%, Romanian version, average completion time 11 minutes and 15 seconds.
3	**Fezabilitate** Feasibility	Ease of administration and processing	Information processing and data collection by physiotherapist and patient/relative during rehabilitation sessions, the short form used is the most manageable, SF-36 OrthoToolKit for data aggregation is licensed (Optum) and freely available online (Rand), for completion 6 minutes online kit completion..
4	**Validitate** Validity	It measures what it claims to measure	Three main types of validity – content, criterion and construct by correlation with other tests proven by the specialized literature. A valid QoL scale shows differences in the expected direction..
5	**Fiabilitate** Reliability	It produces results that are reproducible and internally consistent	It includes stability over time (ie test-retest reliability); between raters or interviewers (ie, interrater reliability); with internal consistency reliability-ICC was applied. To check the internal consistency, the Pearson coefficient was used at T1 and T2 for the control group and the experimental group, respectively.
6	**Receptivitate** Responsiveness	Detect changes over time that matter to patients	Statistical evaluation of effect size, T-test for paired samples, Sign test, Wilcoxon.
7	**Precizie** Precision	It refers to QoL scores – 8 dimensions of health	Refers to cross-checked QoL scores due to the fourth criterion (validity), the use of Likert-type response where degrees of agreement are given by progressive values
8	**Interpretabilitate** Interpretability	Easy-to-understand scores for patients	It means significant and interpretable scores, the Romanian version was used.

The conclusions resulting from the application of the SF-36 questionnaire emerge from the cluster analysis of results at the level of the physical and mental components, summarized with the mention that all the health dimensions evaluated recorded statistically significant values for both groups.

Following the standard and proposed rehabilitation program applied at the level of the control and experimental groups, the following results were obtained at the level of the quality of life at the intergroup level, as well as compared to the norm of the general population.

⇨Intergroup level

- for the physical components summarized at the end of the eight weeks of physical therapy compared to the initial values, an increase of 7.91% of the experimental group (51.73) compared to the standard (47.94);
- for the mental components summarized at the end of the eight weeks of physical therapy compared to the initial values, an increase of 2.75% of the experimental group (55.29) compared to the standard (53.81).

⇨ Normative level

- the control group - minus 4.12% up to the value of 50 for the summarized physical components (47.94) and 7.62% increase above the value of 50 for the summarized mental components (53.81);
- the experimental group - increase of 3.46% above the value of 50 for the summarized physical components (51.73) and of 10.58% above the value of 50 for the summarized mental components (55.29).

The applied questionnaire was analyzed interdependently with the functional results being relevant for the program that included a static horizontal pedal rack - **Figure 15.4.**

Conclusions of the C/E T2/T0 cross-correlated statistical evaluation		
C (n=12), E (n=12)		
Rehabilitation intervention: eight weeks standard/proposed program 50 min, frequency 3 times/week		
Evaluation KIT: RAND 36-Item Health Survey 1.0		
Constructive criteria		
Acceptability 100% response rate Romanian version (New England Medical Center) Average questionnaire completion time = 11 min 15 sec	**Interpretability** Accredited translation into Romanian	**Feasibility** SF-36 OrthoToolKit is licensed by Optum and available free online (Rand), 6 min completion time for the kit
Technical-economic criteria		
Validity Proven by the Medical Outcomes Study and specialized literature	**Precision** Use Likert scales with multiple response options	
Outcome criteria		
Reliability Intraclass correlation coefficient (ICC) evaluated with The Cronbach's Alpha coefficient has a maximum value of 1.000 (optimal value >0.9) for test-retest with two different observers for the control and experimental group at T0 and T2, using the two-way random effects model, p<.000 Consistency was determined with the Pearson correlation coefficient (r) at time T0 and T2 for each group separately.	**Responsiveness** Parametric tests T-Test, and nonparametric sign test, Wilcoxon (Z), p<.000 for the control/experimental group (PF, RP, RE, VT, SF, BP, MH, GH, HC) Determination of the effect size based on the z-score using the partial eta2 factor (η2) for the summarized physical and mental components - relevant effect (>.40) control group η2 = .664 PCS and .651 MCS experimental group η2 = .501 PCS and .537 MCS	
Target criterion - objective		
Appropriateness Answer if the content of the questionnaire corresponds to the main purpose of the study, namely the facilitation of ambulation Application of postural orthostatic stability test (T2) C (12 patients) - the stability score recorded: excellent values 2 (16.7%), very good 5 (41.7%) and 5 normal values (41.7%) E (12 patients) - the stability score registered: excellent values 4 (33.3%), very good 5 (41.7%) and 3 normal values 3 (25%)		

Figure 15.4. Conclusions of the intercorrelated statistical evaluation C/ET2/T0 [Own contribution]

Table 15.6 Responsiveness – Quality of life

T test p<.000; W test p<.002 r	C	E
r(PF)	.650	.703
r(VT)	-	.765
r(MH)	.717	.871
r(SF)	.608	.637
r(GH)	.586	.784

The analysis of the receptivity results **(Table 15.6)** related to the quality of life questionnaire was carried out, for which the proposed rehabilitation program with the horizontal pedal board had a greater statistical relevance for the experimental group in the dimensions of physical functionality (PF), vitality (VT), health mental health (MH), social functionality (SF) and general health (GH).

Multiple regression analysis - ordinary least squares (OLS) for comparing the efficiency of the rehabilitation programs used, taking into account as independent variables the results obtained according to the applied test battery.

The dependent variable is the stability score (proprioception and balance test) obtained after eight weeks of rehabilitation (T2) and the joint balance (BA T2), muscle balance (BM T2), the difference in muscle imbalances between the lower limbs were considered as dependent variables (Dif VAM T2) and the summarized physical components calculated based on the z-score. The results of the multiple regression analysis for the experimental group showed interdependence between the independent variables considered as predictors of estimation adjusted $R2 = .671$, $p=.016$ ($p<.05$). The articular balance has a beta coefficient of .527 with a statistical significance of .045, proving that the simultaneous rhythmic movement involving the triple flexion/extension chain with the help of the static horizontal bicycle led to the validation of the result in favor of the proposed program.

The standard program includes therapeutic exercises applied according to each pathology that mainly targets the injured lower limb.

The rhythmic, symmetrical movement involved in pedaling that simultaneously engages the triple flexion chain and simultaneously the triple extension related to the opposite leg diminishes the differences in muscle strength, corrects alignment and body posture, and re-educates the sensitivity of the injured pelvic limb. The lower limb indem facilitates the movement of the injured lower limb, the agonist-antagonist coactivation being the physiological premise of establishing a normal gesture.

The standard program aims at analytical methods of segmental activation, specific while the proposed program involving static horizontal pedaling involves methods of synthesis, global and synergistic activation, its results being superior in this case.

The final conclusion of the paper is that the built horizontal pedal system proved its efficiency by running the multiple regression analysis that correlated the motor rehabilitation results with those of the quality of life questionnaire.

15.2. OWN CONTRIBUTIONS

The need to approach physical therapy in order to improve the quality of life represents a requirement with multiple valences for the current course of existing pathologies. Stationary bicycles were considered in studies to be safe, feasible, important in maintaining myoarthrokinetic structures and normalizing cardio-pulmonary parameters, preventing and reducing neuromotor deficits.

The development of a horizontal pedal system that addresses patients in the therapeutic window of intervention cumulatively targets musculoskeletal, neurological and cardio-pulmonary medical conditions.

The own contributions in this paper aim at the design, construction and testing of a static horizontal pedaling device, the design of an individualized kinetotherapeutic program depending on the risk associated with each patient, the application of a medical recuperative protocol involving static horizontal pedaling in accordance with the recommendations of the specialist doctor compared to the protocol standard. The evaluation of the results of the SF-36 V1 quality of life questionnaire based on the eight assessment criteria represents an added value, as this aspect has not been comprehensively addressed in the specialized literature, as well as the statistical model of intercorrelation analysis with the rehabilitation test battery.

The design of the device took into account its reliability, the inter-pedal distance of 140 cm, optimally expressed by the self-selected Q factor to ensure the stability of the knee during pedaling, the position of the patient - supine, the active mode of action and the distribution of forces in the kinetic chain controlled. The design of the electrical scheme took into account the safety of use, the transfer of information from the plantar pressure sensors being carried out through the Arduino analog board, whose reliability, usefulness, efficiency in gait analysis has been demonstrated by the specialized literature. The open-source Arduino software (IDE

1.8.19) facilitates writing the code and uploading it to the board, and the Data Streamer application (Microsoft Excel) allows importing, viewing and analyzing live data from the external device - the Arduino microcontroller, in order to evaluate muscle imbalances . The Arduino board returns a value from 0-1024 for any given analog signal corresponding to a 5 volt source. Added to this is the low cost, being a feasible method of design and application. The novelty element represented by the use of the velostat in a double layer of sensors, connected to the Arduino board, leads to an effective highlighting of muscle imbalances expressed in analog values.

The dosage of the therapeutic exercises that involved pedaling was determined according to the riskogram related to each patient. Bio-impedance evaluation was performed to establish the patient's somatotype according to muscle indices (SMI), fat tissue index (FMI) and non-fat tissue index (FFMI). The structure of the pedaling exercise program was established by degrees of difficulty depending on the riskogram: A – high risk, B – moderate risk, C – minimal risk. Periodization, use of passive rest to induce eustress, ensure adherence to treatment, aerobic conditioning, ascending followed by descending protocol were included in the rehabilitation protocol to ensure minimal energy expenditure. The monitoring elements of the rehabilitation program were represented by the assessment of perceived pedaling effort with the Borg scale, heart rate monitoring

The efficiency of the proposed rehabilitation program was compared to a standard program, preliminary experimental research (N=10 subjects) and final (N=24 subjects). We concluded that the rehabilitation program that included the horizontal stationary bicycle achieved better results in terms of pain control and correction of muscle imbalances related to the lower limbs, noting that both programs recorded statistically significant results in terms of functionality.

In order to divide the results at the end of the eight-week rehabilitation period, we applied the stability test, each patient is given a score by correlation with the Zepp Analyzer application according to their proprioception capacity.

The results of the quality of life questionnaire were analyzed summarized in the form of physical and mental components, adjusted with the z-score, compared to a standard norm and the results available at the level of Romania.

The sequence of the analysis of the evaluation criteria of the RAND SF-36 V1 quality of life questionnaire represents an element of originality, these being grouped into constructive criteria (validity and precision), technical-economic criteria (acceptability, feasibility and interpretability), criteria that reflect the results (reliability and responsiveness). Suitability – the target criterion, which answers whether the content of the questionnaire meets the main purpose of the study, namely the facilitation of ambulation, was analyzed with the postural stability test for the assessment of proprioception.

We applied the multiple regression analysis - ordinary least squares (OLS) to compare the efficiency of the rehabilitation programs used, taking into account as independent variables the results obtained according to the battery of tests applied to evaluate motor rehabilitation and as dependent variable the results of the stability test.

The constructed horizontal pedaling system proved its efficiency by running the multiple regression analysis that correlated the motor rehabilitation results with those of the quality of life questionnaire, a correlation that did not prove statistically significant in the case of the standard program, static horizontal pedaling involving synthesis methods, of global and synergistic activation, with superior results in this case.

15.3. PERSPECTIVES

The identified perspectives are the underlining of strategic frameworks to stimulate the rehabilitation process

The first perspective identified so far was the one regarding the importance of the metatarsophalangeal joint related to the hallux in the process of walking rehabilitation (Murgoci & Mereuță, 2021). The personal study presented at the doctoral scientific conference in June 2021 was carried out on 19 patients over 55 years old from the own portfolio from November 2020 - March 2021 diagnosed with various pathologies (except for amputation) affecting the lower limbs and with indications for physiotherapy. Determination of active dorsiflexion and active plantar flexion of the first metatarsophalangeal joint was performed according to the American Medical Association grading scale. If the MTF joint has reduced AM during joint testing, it is an indicative sign of a condition called functional hallux limitus or hallux rigidus. Movement is limited during walking due to ambulation blocking in phase 3 of walking. Kinetic programs can only be used for the first 3 classes depending on the AMA and hallux rigidus severity grades 0-2. The final conclusion of the most important personal study was that in the process of gait rehabilitation, physical therapy can be performed for 12 patients out of 19 for the first MTF joint, among other programs for the kinetic chain to turn the disadvantage of the long immobilization time into the opportunity of rehabilitation correct ambulation (Murgoci & Mereuță, 2021).

The second perspective is to correlate the anti-inflammatory effect of exercises with an appropriate diet, an approach according to a published study that highlights the impact of perception on maintaining adherence in complying with prescriptions related to therapeutic exercises and the related dietary regimen in subjects known to have low back pain (Murgoci, 2022b).

Debates regarding the role of therapeutic exercise and diet as modulators of an anti-inflammatory state have occurred in recent years in the medical community. The synergy between moderate-intensity exercise and an appropriate diet aimed at lowering IL-1 inhibits the production of the pro-inflammatory cytokine TNF-α, the key regulator of local and systemic inflammation. One of the most important causes of short- and long-term disability in all occupational groups is back pain, which affects quality of life. Degeneration of the intervertebral disc (IVD) causes back pain that worsens with age. The Oswestry Disability Index rating was applied to 23 subjects with back pain to investigate the degree of disability. Nutrition of the intervertebral disc, involving therapeutic exercises and a personalized diet can be crucial adjuvants to the rehabilitation process. The appropriate diet and therapeutic exercise approach is designed to assess the impact of awareness on the possibility of improving health outcomes. The educational strategy is essential because implementation of dietary change can elicit resistant behavior as well as adherence to exercise therapy. A key to effective management of the inflammatory state due to various comorbidities is to use the cumulative effects of health professionals' prescriptions. The challenge is to ensure compliance with these actions for each patient (Murgoci, 2022b).

The third perspective consists in encouraging the use of pedaling with the help of a stationary horizontal bicycle in rehabilitation programs, which is a reliable, easy-to-implement tool contributing to improving the quality of life of patients, which has both a therapeutic and diagnostic role, as well as improving the model used by collaboration with a profile company.

DISSEMINATION OF SCIENTIFIC RESULTS

List of published scientific works and participations in scientific conferences during the doctoral studies related to the doctoral thesis entitled: *Unconventional kinetotherapeutic device for motor rehabilitation and improving the quality of life* author PhD Student Murgoci I. Nicolae doctoral school of *SOCIAL-HUMAN SCIENCES* doctoral field *SPORTS AND PHYSICAL EDUCATION SCIENCES* PhD supervisor *Prof. habil. Claudiu MEREUȚĂ, PHD.*

Scientific articles published in BDI/ESCI indexed journals with an impact factor of 1.5

1. Murgoci Nicolae - **The importance of body composition assessment in the rehabilitation process.** Balneo and PRM Research Journal 2021, **2021;12(4):352–364 DOI 10.12680/balneo.2021.463**

2. Murgoci Nicolae – Comparative study on the efficiency of motor rehabilitation of the lower limbs using a stationary horizontal bicycle versus a standard therapeutic program. Balneo and PRM Research Journal 2022, 13(4): 524, **DOI 10.12680/balneo.2022.524** factor de impact **1.5**

3. Murgoci Nicolae - The impact of perception regarding therapeutic exercises and dietary changing adherence of subjects known with low back pain.Balneo and PRM Research Journal 2022, 13(4): 525 **DOI 10.12680/balneo.2022.525** factor de impact **1.5**

4. Murgoci Nicolae – Quality of life outcomes evaluation after motor rehabilitation of the lower limbs using a stationary bicycle. Balneo and PRM Research Journal 2023, 14(1): 533, **DOI 10.12680/balneo.2023.533** factor de impact **1.5**

Scientific articles published in BDI indexed journals

5. Murgoci, N. and Mereuță, C. (2021) "ASPECTS OF THE IMPORTANCE OF FIRST METATARSOPHALANGEAL JOINT IN THE PROCESS OF GAIT RECOVERY", *Annals of "Dunarea de Jos" University of Galati. Fascicle XV, Physical Education and Sport Management*, 1, pp. 20-32. **https://doi.org/10.35219/efms.2021.1.02.**

6. Murgoci, N., Mereuță, C. and Nanu, L. (2022) "DOSAGE OF THERAPEUTIC EXERCISE ACCORDING TO PATIENTS' RISK CHART DETERMINED BY BIOIMPEDANCE", *Annals of "Dunarea de Jos" University of Galati. Fascicle XV, Physical Education and Sport Management*, 1, pp. 34-62. doi: **https://doi.org/10.35219/efms.2022.1.04**.

7. Murgoci, N., Mereuță, C. and Ganea, D. (2022) "GAIT FACILITATION PROGRAM USING A HORIZONTAL BICYCLE BUILT AND DESIGNED TO MONITOR KINETIC CHAIN PARAMETERS – CASE STUDY", *Annals of "Dunarea de Jos" University of Galati. Fascicle XV, Physical Education and Sport Management*, 1, pp. 63-78. doi: **https://doi.org/10.35219/efms.2022.1.05.**

Papers presented at scientific conferences

8. **Murgoci, Nicolae**; Mereuță, Claudiu "ASPECTS OF THE IMPORTANCE OF FIRST METATARSOPHALANGEAL JOINT IN THE PROCESS OF GAIT RECOVERY" "Dunarea de Jos" University of Galati. 9th Edition of *SCDS-UDJG* **S.15.** Advanced research in human motricity and kinetotherapy, Book of abstracts pp. 216
https://cssd-udjg.ugal.ro/index.php/en/abstracts-2021

9. **Murgoci, Nicolae**; Mereuță, Claudiu. "DOSAGE OF THERAPEUTIC EXERCISE ACCORDING TO PATIENTS' RISK CHART DETERMINED BY BIOIMPEDANCE" "Dunarea de Jos" University of Galati. 10th Edition of *SCDS-UDJG* **S.15.** Advanced research in human motricity and kinetotherapy, Book of abstracts pp. 185
https://cssd-udjg.ugal.ro/index.php/en/abstracts-2022

10. **Murgoci, Nicolae**; Mereuță, Claudiu "GAIT FACILITATION PROGRAM USING A HORIZONTAL BICYCLE BUILT AND DESIGNED TO MONITOR KINETIC CHAIN PARAMETERS – CASE STUDY" "Dunarea de Jos" University of Galati. 10th Edition of *SCDS-UDJG* **S.15.** Advanced research in human motricity and kinetotherapy, Book of abstracts pp. 187
https://cssd-udjg.ugal.ro/index.php/en/abstracts-2022

11. **Murgoci Nicolae**- PROMOTORS INDUCING POSITIVE EFFECTS ON ARTICULAR NUTRITION "Dunarea de Jos" University of Galati. 11th Edition of *SCDS-UDJG* **S.15.** Advanced research in human motricity and kinetotherapy, Book of abstracts pp. 230
https://cssd-udjg.ugal.ro/images/2023/10/Book%20of%20abstract%202023%20(1).pdf

12. **Murgoci Nicolae**- RESPONSIVENESS QUALITY OF LIFE ASSESSMENT, "Dunarea de Jos" University of Galati. 11th Edition of *SCDS-UDJG* **S.15.** Advanced research in human motricity and kinetotherapy, Book of abstracts pp. 232
https://cssd-udjg.ugal.ro/images/2023/10/Book%20of%20abstract%202023%20(1).pdf

BIBLIOGRAPHY

[1] Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Neural adaptation to resistance training: Changes in evoked V-wave and H-reflex responses. *Journal of Applied Physiology*, *92*(6), 2309–2318. https://doi.org/10.1152/japplphysiol.01185.2001
[2] Abbiss, C. R., & Laursen, P. . (2008). Describing and Understanding Pacing Strategies during Athletic Competition. *Sports Medicine*, *38*(3), 239–252. https://doi.org/10.2165/00007256-200838030-00004
[3] Altex.ro. (2021). *Cablu USB A - USB B HAMA 20180, 1*. Altex.Ro. https://altex.ro/cablu-usb-a-usb-b-hama-20180-1-5m-negru/cpd/CAB20180/#additional
[4] Anita L. Stewart and John E. Ware. (1992). Summary and Discussion of MOS Measures, published in: Measuring Functioning and Well-Being: The Medical Outcomes Study Approach. In *Duke University Press* (pp. 345–371). Durham, N.C.: Duke University Press. https://www.rand.org/pubs/external_publications/EP19920054.html
[5] Anita L. Stewart, J. E. W. J. (1992). Measuring Functioning and Well-Being The Medical Outcomes Study Approach. In *Duke University Press Books*. Duke University Press Books. https://doi.org/10.7249/CB361
[6] Arakawa, T., Otani, T., Tanaka, M., & Kobayashi, Y. (2018). Computational study on motion criterion and muscle activity pattern in elderly gait with muscle weakness. *ACM International Conference Proceeding Series*, 118–121. https://doi.org/10.1145/3301879.3301891
[7] Arduino.cc. (2021). *Arduino IDE 2*. Arduino.Cc. https://www.arduino.cc/en/software
[8] Avers, D., & Brown, M. (2019). Daniels and Worthingham's Muscle Testing: Techniques of Manual Examination and Performance Testing 10th edition. In *Elsevier Inc.*
[9] Barnes, K. A., Kroening-Roche, J. C., & Comfort, B. W. (2012). The Developing Vision of Primary Care. *New England Journal of Medicine*, *367*(10), 891–893. https://doi.org/10.1056/NEJMp1204487
[10] Beckers, D., & Buck, M. (2021). PNF in Practice An Illustrated Guide Fifth Edition. In *Springer Verlag GmbH*. https://doi.org/10.1007/978-3-662-61818-9
[11] Benatti, F. B., & Pedersen, B. K. (2014). Exercise as an anti-inflammatory therapy for rheumatic diseases - Myokine regulation. *Nature Reviews Rheumatology*, *11*(2), 86–97. https://doi.org/10.1038/nrrheum.2014.193
[12] Bessler, J., Prange-Lasonder, G. B., Schaake, L., Saenz, J. F., Bidard, C., Fassi, I., Valori, M., Lassen, A. B., & Buurke, J. H. (2021). Safety Assessment of Rehabilitation Robots: A Review Identifying Safety Skills and Current Knowledge Gaps. *Frontiers in Robotics and AI*, *8*(March), 1–18. https://doi.org/10.3389/frobt.2021.602878
[13] Borg, G. A. V. (1982). Psychophysical bases of perceived exertion. In *Medicine and Science in Sports and Exercise* (Vol. 14, Issue 5, pp. 377–381). https://doi.org/10.1249/00005768-198205000-00012
[14] Bouillon, L., Baker, R., Gibson, C., Kearney, A., & Busemeyer, T. (2016). Comparison of Trunk and Lower Extremity Muscle Activity Among Four Stationary Equipment Devices: Upright Bike, Recumbent Bike, Treadmill, and Elliptigo®. *International Journal of Sports Physical Therapy*, *11*(2), 190–200. http://www.ncbi.nlm.nih.gov/pubmed/27104052%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4827362
[15] Braddom, R. (2011). Medicina Fizica si de Reabilitare Ediţia a IV-a. In *Societatea Romana de Reabilitare medicala*.
[16] Brandl, C., Rasche, P., Bröhl, C., Theis, S., Wille, M., Schlick, C. M., & Mertens, A. (2017). Incentives for the acceptance of mobility equipment by elderly people on the basis of the Kano model: A human factors perspective for initial contact with healthcare products. In *Advances in Human Factors and Ergonomics in Healthcare* (Vol. 482, pp. 161–171). https://doi.org/10.1007/978-3-319-41652-6_16
[17] Brazier, J. E., Harper, R., Munro, J., Walters, S. J., & Snaith, M. L. (1999). Generic and condition-specific outcome measures for people with osteoarthritis of the knee. *Rheumatology*, *38*(9), 870–877. https://doi.org/10.1093/rheumatology/38.9.870

[18] Brazier, J. E., Walters, S. J., Nicholl, J. P., & Kohler, B. (1996). Using the SF-36 and euroqol on an elderly population. *Quality of Life Research*, *5*(2), 195–204. https://doi.org/10.1007/BF00434741

[19] Burke, D. (2016). Clinical uses of H reflexes of upper and lower limb muscles. *Clinical Neurophysiology Practice*, *1*, 9–17. https://doi.org/10.1016/j.cnp.2016.02.003

[20] C. Drugă 1, I. Ş. (2017). Study of Foot Pressure- Sole Pressure Sensor. *Transilvania University Press of Brasov*, 132–135.

[21] Carolyn Kisner, Lynn Allen Colby, J. B. (2018). Therapeutic Exercise: Foundations and Techniques 7th Edition. In *F. A. Davis Company Copyright*. F. A. Davis Company Copyright.

[22] Cieza, A., Causey, K., Kamenov, K., Hanson, S. W., Chatterji, S., & Vos, T. (2020). Global estimates of the need for rehabilitation based on the Global Burden of Disease study 2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*, *396*(10267), 2006–2017. https://doi.org/10.1016/S0140-6736(20)32340-0

[23] Clark, B. C., & Manini, T. M. (2010). Functional consequences of sarcopenia and dynapenia in the elderly. *Current Opinion in Clinical Nutrition and Metabolic Care*, *13*(3), 271–276. https://doi.org/10.1097/MCO.0b013e328337819e

[24] Coherent Market Insights. (2018). *Rehabilitation Robots Market Analysis, Rehabilitation Robots Market - Global Industry Insights, Trends, Outlook, and Opportunity Analysis, 2018-2026*. Coherent Market Insights. https://www.coherentmarketinsights.com/market-insight/rehabilitation-robots-market-406

[25] Cortis, C., Fusco, A., Cook, M., Doberstein, S. T., Gillette, C., Porcari, J. P., & Foster, C. (2021). Indoor cycling energy expenditure: Does sequence matter? *International Journal of Environmental Research and Public Health*, *18*(3), 1–8. https://doi.org/10.3390/ijerph18030870

[26] Cotârlă, L. (2009). Posibilităţi de optimizare a calităţii vieţii la bolnavii renali, dializaţi cronic, rezultate. *Acta Medica Transilvanica*, *II*(4), 74–75. http://www.amtsibiu.ro/Arhiva/2009/Nr4/AC/Cotarla-rezultate-ro.pdf

[27] Croser, R., Garrett, R., Seeger, B., & Davies, P. (2001). Effectiveness of electronic aids to daily living: Increased independence and decreased frustration. *Australian Occupational Therapy Journal*, *48*(1), 35–44. https://doi.org/10.1046/j.1440-1630.2001.00236.x

[28] Cruz-Jentoft, A. J., Bahat, G., Bauer, J., Boirie, Y., Bruyère, O., Cederholm, T., Cooper, C., Landi, F., Rolland, Y., Sayer, A. A., Schneider, S. M., Sieber, C. C., Topinkova, E., Vandewoude, M., Visser, M., Zamboni, M., Bautmans, I., Baeyens, J. P., Cesari, M., … Schols, J. (2019). Sarcopenia: Revised European consensus on definition and diagnosis. *Age and Ageing*, *48*(1), 16–31. https://doi.org/10.1093/ageing/afy169

[29] Dana Rusten. (2015). *Tendon Outline Function Structure Mechanical Properties, online couses*. Slideplayer.Com. https://slideplayer.com/slide/3815654/

[30] Dedeman.ro. (2021a). *Adeziv bicomponent universal, Bison Epoxy, aspect metalic, 24 ml*. Dedeman.Ro. https://www.dedeman.ro/ro/adeziv-bicomponent-universal-bison-epoxy-aspect-metalic-24-ml/p/5000145

[31] Dedeman.ro. (2021b). *Surub autofiletant pentru tabla, cu cap plat saiba, din otel, zincat alb, 4*. Dedeman.Ro. https://www.dedeman.ro/ro/surub-autofiletant-pentru-tabla-cu-cap-plat-saiba-din-otel-zincat-alb-4-2-x-25-mm/p/1022111

[32] Delgado, D. A., Lambert, B. S., Boutris, N., McCulloch, P. C., Robbins, A. B., Moreno, M. R., & Harris, J. D. (2018). Validation of Digital Visual Analog Scale Pain Scoring With a Traditional Paper-based Visual Analog Scale in Adults. *Journal of the American Academy of Orthopaedic Surgeons JAAOS: Global Research and Reviews*, *2*(3), e088. https://doi.org/10.5435/jaaosglobal-d-17-00088

[33] Dijk, H. Van, Megen, R. Van, & Vroemen, G. (2017). The Secret of Cycling. In *Meyer & Meyer Sport (UK) Ltd.*

[34] Dimitrov, S., Hulteng, E., & Hong, S. (2017). Inflammation and exercise: Inhibition of monocytic intracellular TNF production by acute exercise via β2-adrenergic activation. *Brain, Behavior, and Immunity*, *61*, 60–68. https://doi.org/10.1016/j.bbi.2016.12.017

[35] Disley, B. X., & Li, F. X. (2014). The effect of Q Factor on gross mechanical efficiency and muscular activation in cycling. *Scandinavian Journal of Medicine and Science in*

Sports, *24*(1), 117–121. https://doi.org/10.1111/j.1600-0838.2012.01479.x
[36] Disley, Benedict Xavier, & Li, F. X. (2014). Metabolic and kinematic effects of self-selected Q factor during bike fit. *Research in Sports Medicine*, *22*(1), 12–22. https://doi.org/10.1080/15438627.2013.852093
[37] Doi, T., Akai, M., Fujino, K., Iwaya, T., Kurosawa, H., Hayashi, K., & Marui, E. (2008). Effect of home exercise of quadriceps on knee osteoarthritis compared with nonsteroidal antiinflammatory drugs: A randomized controlled trial. *Lippincott Williams and Wilkins*, *87*(4), 258–269. https://doi.org/10.1097/PHM.0b013e318168c02d
[38] Duncan RL, T. C. (1995). Mechanotransduction and the Functional Response of Bone to Mechanical Strain. *Calcif Tissue Int*, *57*(5), 344–358. https://doi.org/10.1007/BF00302070
[39] Dunleavy, K., & Slowik, A. K. (2019). THERAPEUTIC EXERCISE PRESCRIPTION. In *Elsevier*.
[40] Elizabeth Bryan. (2018). The Comprehensive Manual of Therapeutic Exercises Orthopedic and General Conditions. In *Slack Incorporated*.
[41] Ellenbecker, B. T. S., & Davies, G. J. (2001). Closed Kinetic Chain Exercise: A Comprehensive Guide to Multiple Joint Exercise. *Human Kinetics Publishers*.
[42] Emag.ro. (2021a). *Banda izolatoare autoadeziva Kapton tape 80mm x 30m*. Emag.Ro. https://www.emag.ro/banda-izolatoare-autoadeziva-kapton-tape-80mm-x-30m-10105845/pd/D17R47MBM/
[43] Emag.ro. (2021b). *Folie conductiva cu rezistenta variabila cu presiunea - Velostat, dimensiune 30x30 cm*. Emag.Ro. https://www.emag.ro/folie-conductiva-cu-rezistenta-variabila-cu-presiunea-velostat-dimensiune-30x30-cm-01ff/pd/DDFWSWBBM/
[44] EMITENT MINISTERUL SĂNĂTĂȚII. (2021). *ORDIN nr. 534 din 22 aprilie 2021 pentru aprobarea Protocolului de medicină fizică și de reabilitare post-COVID-19*. MONITORUL OFICIAL Nr. 439 Din 26 Aprilie 2021. https://legislatie.just.ro/Public/DetaliiDocument/241643
[45] Enoka, R. M. (2008). Neuromechanics of Human Movement. In *Human Kinetics*. https://doi.org/10.5040/9781492595632
[46] Escamilla, R. F., Fleisig, G. S., Zheng, N., Barrentine, S. W., Wilk, K. E., & Andrews, J. R. (1998). Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Medicine and Science in Sports and Exercise*, *30*(4), 556–569. https://doi.org/10.1097/00005768-199804000-00014
[47] Evans, W. J. (2010). Skeletal muscle loss: Cachexia, sarcopenia, and inactivity. *American Journal of Clinical Nutrition*, *91*(4), 1123–1127. https://doi.org/10.3945/ajcn.2010.28608A
[48] Farjadian, A. B., Kong, Q., Gade, V. K., Deutsch, J. E., & Mavroidis, C. (2013). VRACK: Measuring pedal kinematics during stationary bike cycling. *2013 IEEE 13th International Conference on Rehabilitation Robotics (ICORR), Seattle, WA, USA*, 1–6. https://doi.org/10.1109/ICORR.2013.6650453
[49] Farshad Fani Marvasti, R. S. S. (2012). From sick care to health care--reengineering prevention into the U.S. system. *The New England Journal of Medicine*, *367*(10), 889–891. https://doi.org/10.1056/NEJMp1206230
[50] Fernandes, T. (2006). Independent mobility for children with disabilities. *International Journal of Therapy and Rehabilitation*, *13*(7), 329–333. https://doi.org/10.12968/ijtr.2006.13.7.21410
[51] Fisher, M. I., & Harrington, S. (2015). Research Round-up : Manual Muscle Testing. *Rehabilitation Oncology*, *33*, 1–2. https://doi.org/10.3791/2632.5.Hough
[52] Fitzpatrick, R., Davey, C., Buxton, M. J., & Jones, D. R. (1998). Evaluating patient-based outcome measures for use in clinical trials. *Health Technology Assessment*, *2*(14). https://doi.org/10.3310/hta2140
[53] Foster, A. (2019). Mechanisms and Mitigation of Skeletal Muscle Fatigue in Single Fibers from Older Adults. *University of Massachusetts Amherst*, *July*, 1–89. https://scholarworks.umass.edu/masters_theses_2
[54] Foster, C., Dekoning, J. J., Hettinga, F., Lampen, J., Dodge, C., Bobbert, M., & Porcari, J. P. (2004). Effect of competitive distance on energy expenditure during simulated competition. *International Journal of Sports Medicine*, *25*(3), 198–204.

https://doi.org/10.1055/s-2003-45260

[55] Foster, Carl;, de Koning, J., Bischel, S., Casalino, E., Malterer, K., O'Brien, K., Rodriguez-Marroyo, J., Splinter, A., Thiel, C., & van Tunen, J. (2012). Chapter: 9 Pacing Strategies for Endurance Performance. In Inigo Mujika (Ed.), *Endurance Training: Science and Practice*. Inigo Mujika. https://www.researchgate.net/publication/299500462_Pacing_Strategies_for_Endurance_Performance

[56] Foster, Carl, Schrager, M., Snyder, A. C., & Thompson, N. N. (1994). Pacing Strategy and Athletic Performance. *Sports Medicine*, *17*(2), 77–85. https://doi.org/10.2165/00007256-199417020-00001

[57] Fransen, M., McConnell, S., & Bell, M. (2002). Therapeutic exercise for people with osteoarthritis of the hip or knee. A systematic review. *Journal of Rheumatology*, *29*(8), 1737–1745. https://www.jrheum.org/content/jrheum/29/8/1737.full.pdf

[58] Frost, H. M. (1983). 067 A Determinant of Bone Architecture The Minimum Effective Strain. *Clinical Orthopaedics and Related Research*, 286–292.

[59] Frost, H. M. (1997). Defining osteopenias and osteoporoses: Another view (with insights from a new paradigm). *Bone*, *20*(5), 385–391. https://doi.org/10.1016/s8756-3282(97)00019-7

[60] Frost, H. M. (2000). The Utah paradigm of skeletal physiology: An overview of its insights for bone, cartilage and collagenous tissue organs. *Journal of Bone and Mineral Metabolism*, *18*(6), 305–316. https://doi.org/10.1007/s007740070001

[61] garagegymplanner.com. (2020). *Best Mini Exercise Bikes For Home Workout in 2019*. Garagegymplanner.Com. https://garagegymplanner.com/best-mini-exercise-bike-reviews/

[62] Garratt, A., Schmidt, L., Mackintosh, A., & Fitzpatrick, R. (2002). Quality of life measurement: bibliographic study of patient assessed health outcome measures. *BMJ*, *324*(February 2009). https://doi.org/10.1136/bmj.324.7351.1417

[63] Gassert, R., & Dietz, V. (2018). Rehabilitation robots for the treatment of sensorimotor deficits: A neurophysiological perspective. *Journal of NeuroEngineering and Rehabilitation*, *15*(1), 1–15. https://doi.org/10.1186/s12984-018-0383-x

[64] George Serban. (1976). Stress without Distress from Psychopathology of Human Adaptation. In *Springer Science+Business Media ILLC*. https://doi.org/10.1007/978-1-4684-2238-2

[65] Gielen, S., Adams, V., Möbius-Winkler, S., Linke, A., Erbs, S., Yu, J., Kempf, W., Schubert, A., Schuler, G., & Hambrecht, R. (2003). Anti-inflammatory effects of exercise training in the skeletal muscle of patients with chronic heart failure. *Journal of the American College of Cardiology*, *42*(5), 861–868. https://doi.org/10.1016/S0735-1097(03)00848-9

[66] Glass, R., Waddell, J., & Hoogenboom, B. (2010). The Effects of Open versus Closed Kinetic Chain Exercises on Patients with ACL Deficient or Reconstructed Knees: A Systematic Review. *North American Journal of Sports Physical Therapy : NAJSPT*, *5*(2), 74–84. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2953392/

[67] Gould, D., Kelly, D., Goldstone, L., & Gammon, J. (2001). Examining the validity of pressure ulcer risk assessment scales: developing and using illustrated patient simulations to collect the data INFORMATION POINT: Visual Analogue Scale. *Journal of Clinical Nursing*, *10*, 697–706. https://doi.org/10.1046/j.1365-2702.2001.00525.x

[68] Grand View Rresearch. (2018). *Rehabilitation Equipment Market Size, Share & Trends Analysis Report By Product Type (Daily Living Aids, Mobility Equipment, Exercise Equipment, Body Support Devices), By Application, By End-use, By Region, And Segment Forecasts, 2018 - 2025*. Grand View Rresearch. https://www.grandviewresearch.com/industry-analysis/rehabilitation-products-market

[69] Grenez, F., Viqueira Villarejo, M., García Zapirain, B., & Méndez Zorrilla, A. (2013). Wireless prototype based on pressure and bending sensors for measuring gate quality. *Sensors (Switzerland)*, *13*(8), 9679–9703. https://doi.org/10.3390/s130809679

[70] Hackney, K. J., Scott, J. M., Hanson, A. M., English, K. L., Downs, M. E., & Ploutz-Snyder, L. L. (2015). The Astronaut-Athlete: Optimizing Human Performance in Space. *Journal of Strength and Conditioning Research*, *29*(12), 3531–3545.

https://doi.org/10.1519/JSC.0000000000001191

[71] Haefeli, M., & Elfering, A. (2006). Pain assessment. *European Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *15*(SUPPL. 1), 17–24. https://doi.org/10.1007/s00586-005-1044-x

[72] Hand, C. (2016). Measuring health-related quality of life in adults with chronic conditions in primary care settings: Critical review of concepts and 3 tools. *Canadian Family Physician*, *62*(7), e375–e383. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4955103/

[73] Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, M. L., Genevay, S., Hoy, D., Karppinen, J., Pransky, G., Sieper, J., Smeets, R. J., Underwood, M., Buchbinder, R., Cherkin, D., Foster, N. E., Maher, C. G., van Tulder, M., Anema, J. R., Chou, R., … Woolf, A. (2018). What low back pain is and why we need to pay attention. *The Lancet*, *391*(10137), 2356–2367. https://doi.org/10.1016/S0140-6736(18)30480-X

[74] Hattori, K., Tatsumi, N., & Tanaka, S. (1997). Assessment of Body Composition by Using a New Chart Method. *American Journal of Human Biology*, *9*(5), 573–578. https://doi.org/10.1002/(SICI)1520-6300(1997)9:5<573::AID-AJHB5>3.0.CO;2-V

[75] Hays RD, S. M. (1992). An overview of generic health-related quality of life measures for HIV research. *Quality of Life Research*, *1*(2), 91–97. https://doi.org/10.1007/BF00439716

[76] Helbostad, J. L., & Moe-Nilssen, R. (2003). The effect of gait speed on lateral balance control during walking in healthy elderly. *Gait and Posture*, *18*(2), 27–36. https://doi.org/10.1016/s0966-6362(02)00197-2

[77] Hjermstad, M. J., Fayers, P. M., Haugen, D. F., Caraceni, A., Hanks, G. W., Loge, J. H., Fainsinger, R., Aass, N., & Kaasa, S. (2011). Studies comparing numerical rating scales, verbal rating scales, and visual analogue scales for assessment of pain intensity in adults: A systematic literature review. *Journal of Pain and Symptom Management*, *41*(6), 1073–1093. https://doi.org/10.1016/j.jpainsymman.2010.08.016

[78] Hoffman, J. M., Bell, K. R., Powell, J. M., Behr, J., Dunn, E. C., Dikmen, S., & Bombardier, C. H. (2010). A Randomized Controlled Trial of Exercise to Improve Mood After Traumatic Brain Injury. *PM and R*, *2*(10), 911–919. https://doi.org/10.1016/j.pmrj.2010.06.008

[79] Hollman, J. H., Youdas, J. W., & Lanzino, D. J. (2011). Gender differences in dual task gait performance in older adults. *American Journal of Men's Health*, *5*(1), 11–17. https://doi.org/10.1177/1557988309357232

[80] Hoover, D. L., VanWye, W. R., & Judge, L. W. (2016). Periodization and physical therapy: Bridging the gap between training and rehabilitation. *Physical Therapy in Sport*, *18*(February 2016), 1–20. https://doi.org/10.1016/j.ptsp.2015.08.003

[81] Hu, S., Mendonca, R., Johnson, M. J., & Kuchenbecker, K. J. (2020). Robotics for occupational therapy: Learning upper-limb exercises from demonstrations. *IEEE Robotics and Automation Letters*, *6*(4), 7781–7788. https://doi.org/10.1109/LRA.2021.3098945

[82] Huang, C., & Ogawa, R. (2010). Mechanotransduction in bone repair and regeneration. *FASEB Journal*, *24*(10), 3625–3632. https://doi.org/10.1096/fj.10-157370

[83] HUAWEI. (2021). *HUAWEI WATCH GT 2*. HUAWEI. https://consumer.huawei.com/en/wearables/watch-gt2/

[84] Hug, F., Turpin, N. A., Guével, A., & Dorel, S. (2010). Is interindividual variability of EMG patterns in trained cyclists related to different muscle synergies? *Journal of Applied Physiology*, *108*(6), 1727–1736. https://doi.org/10.1152/japplphysiol.01305.2009

[85] Hussain, S., Jamwal, P. K., Vliet, P. V., & Brown, N. A. T. (2021). Robot Assisted Ankle Neuro-Rehabilitation: State of the art and Future Challenges. *Expert Review of Neurotherapeutics*, *21*(1), 111–121. https://doi.org/10.1080/14737175.2021.1847646

[86] Institute for Health Metrics and Evaluation. (2020). *WHO Rehabilitation Need Estimator. Rehabilitation is not a service for the few*. Vizhub.Healthdata.Org. https://vizhub.healthdata.org/rehabilitation/

[87] Intelligence, M. (2021). *Mordor Intelligence, Rehabilitation Equipment Market - Growth, Trends, Covid-19*. Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/rehabilitation-equipment-market

[88] Jesse Maida. (2017). *Rehabilitation Robots Market - Opportunity Assessment and Global Forecast by Technavio*. Business Wire. https://www.businesswire.com/news/home/20170707005508/en/Rehabilitation-Robots-Market---Opportunity-Assessment-and-Global-Forecast-by-Technavio

[89] Jin, L., Min, G., Wei, C., Min, H., & Jie, Z. (2017). Exercise training on chronotropic response and exercise capacity in patients with type 2 diabetes mellitus. *Experimental and Therapeutic Medicine*, *13*(3), 899–904. https://doi.org/10.3892/etm.2017.4084

[90] John E Ware, K., S. K., Mark, K., & Barbara, G. (1993). SF36 Health survey : Manual and Interpretation Guided. In *Nimrod Press Inc Boston Massachusetts*. https://www.researchgate.net/publication/247503121_SF36_Health_Survey_Manual_and_Interpretation_Guide

[91] Jor, A., Das, S., Bappy, A. S., & Rahman, A. (2019). Foot Plantar Pressure Measurement Using Low Cost Force Sensitive Resistor (FSR): Feasibility Study. *Journal of Scientific Research*, *11*(3), 311–319. https://doi.org/10.3329/jsr.v11i3.40581

[92] Joseph Hamill, Kathleen M. Knutzen, T. R. D. (2015). Biomechanical basis of human movement. In *Lippincott Williams & Wilkins, a Wolters Kluwer business*.

[93] Julius Wolff. (1986). The Law of Bone Remodelling. In *Springer-Verlag Berlin Heidelberg*. https://doi.org/10.1007/978-3-642-71031-5

[94] Jutai, J., Rigby, P., Ryan, S., & Stickel, S. (2000). Psychosocial Impact of Electronic Aids to Daily Living. *Assistive Technology: The Official Journal of RESNA*, *12*(2), 123–131. https://doi.org/10.1080/10400435.2000.10132018

[95] Kang, J., Schweitzer, J. S., & Hoffman, J. R. (2003). Effect of order of exercise intensity upon cardiorespiratory, metabolic, and perceptual responses during exercise of mixed intensity. *European Journal of Applied Physiology*, *90*(5–6), 569–574. https://doi.org/10.1007/s00421-003-0908-1

[96] Karandikar, N., & Vargas, O. O. O. (2011). Kinetic Chains: A Review of the Concept and Its Clinical Applications. *PM and R*, *3*(8), 739–745. https://doi.org/10.1016/j.pmrj.2011.02.021

[97] Karapolat, H., Eyigor, S., Zoghi, M., Yagdi, T., Nalbantgil, S., Durmaz, B., & Ozbaran, M. (2008). Effects of cardiac rehabilitation program on exercise capacity and chronotropic variables in patients with orthotopic heart transplant. *Clinical Research in Cardiology*, *97*(7), 449–456. https://doi.org/10.1007/s00392-008-0648-7

[98] Kaya, D., Doral, M. N., & Callaghan, M. (2012). How can we strengthen the quadriceps femoris in patients with patellofemoral pain syndrome? *Muscles, Ligaments and Tendons Journal*, *2*(1), 25–32. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3666499/

[99] Keller, K., & Engelhardt, M. (2013). Strength and muscle mass loss with aging process. Age and strength loss. *Muscles, Ligaments and Tendons Journal*, *3*(4), 346–350. https://doi.org/10.11138/mltj/2013.3.4.346

[100] Keteyian, S. J., Brawner, C. A., Schairer, J. R., Levine, T. B., Levine, A. B., Rogers, F. J., & Goldstein, S. (1999). Effects of exercise training on chronotropic incompetence in patients with heart failure. *American Heart Journal*, *138*(2 I), 233–240. https://doi.org/10.1016/S0002-8703(99)70106-7

[101] Kho, M. E., Martin, R. A., Toonstra, A. L., Zanni, J. M., Mantheiy, E. C., Nelliot, A., & Needham, D. M. (2015). Feasibility and safety of in-bed cycling for physical rehabilitation in the intensive care unit. *Journal of Critical Care*, *30*(6), 1419.e1-1419.e5. https://doi.org/10.1016/j.jcrc.2015.07.025

[102] Kho, M. E., Molloy, A. J., Clarke, F. J., Ajami, D., McCaughan, M., Obrovac, K., Murphy, C., Camposilvan, L., Herridge, M. S., Koo, K. K. Y., Rudkowski, J., Seely, A. J. E., Zanni, J. M., Mourtzakis, M., Piraino, T., & Cook, D. J. (2016). TryCYCLE: A prospective study of the safety and feasibility of early in-bed cycling in mechanically ventilated patients. *PLoS ONE*, *11*(12), 1–17. https://doi.org/10.1371/journal.pone.0167561

[103] Klimek, L., Bergmann, K. C., Biedermann, T., Bousquet, J., Hellings, P., Jung, K., Merk, H., Olze, H., Schlenter, W., Stock, P., Ring, J., Wagenmann, M., Wehrmann, W., Mösges, R., & Pfaar, O. (2017). Visual analogue scales (VAS): Measuring instruments for the documentation of symptoms and therapy monitoring in cases of allergic rhinitis in everyday health care: Position Paper of the German Society of Allergology (AeDA) and the German Society of Al. *Allergo Journal International*, *26*(1), 16–24.

https://doi.org/10.1007/s40629-016-0006-7

[104] Laucis, N. C., Hays, R. D., & Bhattacharyya, T. (2015). Scoring the SF-36 in orthopaedics: A brief guide. *Journal of Bone and Joint Surgery - American Volume*, *97*(19), 1628–1634. https://doi.org/10.2106/JBJS.O.00030

[105] Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., Corsi, A. M., Rantanen, T., Guralnik, J. M., & Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003

[106] Lee, J. H., & Jun, H. S. (2019). Role of myokines in regulating skeletal muscle mass and function. *Frontiers in Physiology*, *10*(JAN), 1–9. https://doi.org/10.3389/fphys.2019.00042

[107] Leelayuwat, N. (2017). Exercise Therapy for Physical Therapist. *Clinical Physical Therapy*, *1*, 75–94. https://doi.org/10.5772/intechopen.68390

[108] Li, L., Fu, Q., Tyson, S., Preston, N., & Weightman, A. (2022). A scoping review of design requirements for a home-based upper limb rehabilitation robot for stroke. *Topics in Stroke Rehabilitation*, *29*(6), 449–463. https://doi.org/10.1080/10749357.2021.1943797

[109] Maculewicz, J., Serafin, S., & Kofoed, L. (2015). A Stationary Bike in Virtual Reality-Rhythmic Exercise and Rehabilitation. *Doctoral Consortium on Biomedical Engineering Systems and Technologies*, *2*(2003), 3–8. https://doi.org/10.5220/0005324700030008

[110] Mardare, I., Furtunescu, F. L., & Bratu, E. C. (2019). Measuring Health Related Quality of Life-Methods and Tools. *Acta Medica Transilvanica*, *24*(2), 6–8.

[111] Marilyn Bradbury, Elizabeth Bennison, Helen Mason, J. G. (2021). Tools for participation: living aids and the F-words for childhood development. *Paediatrics and Child Health*, *31*(9), 352–358. https://doi.org/https://doi.org/10.1016/j.paed.2021.06.004

[112] Markets and Markets. (2020). *Rehabilitation Equipment Market Global Forecast*. Markets and Markets. https://www.marketsandmarkets.com/Market-Reports/rehabilitation-equipment-market-194775519.html

[113] McPherson, J. G., McPherson, L. M., Thompson, C. K., Ellis, M. D., Heckman, C. J., & Dewald, J. P. A. (2018). Altered neuromodulatory drive may contribute to exaggerated tonic vibration reflexes in chronic hemiparetic stroke. *Frontiers in Human Neuroscience*, *12*(April), 1–15. https://doi.org/10.3389/fnhum.2018.00131

[114] Microsoft.com. (2021). *Microsoft Data Streamer*. Microsoft.Com. https://www.microsoft.com/en-us/download/details.aspx?id=56976

[115] MINISTERUL SĂNĂTĂȚII. (2021). *Ordin pentru aprobarea Protocolului de medicină fizică şi de reabilitare post-COVID-19*. MONITORUL OFICIAL Nr. 439 Din 26 Aprilie 2021. https://legislatie.just.ro/Public/DetaliiDocument/241643

[116] Mordor Intelligence LLP. (2021). *Rehabilitation Equipment Market - Growth, Trends, Covid-19 Impact, and Forecasts (2021 - 2026)*. Reportlinker.Com; Mordor Intelligence LLP. https://www.reportlinker.com/p06039524/Rehabilitation-Equipment-Market-Growth-Trends-Covid-19-Impact-and-Forecasts.html

[117] Morin, J.-B. P. S. (2018). Biomechanics of Training and Testing- Innovative Concepts and Simple Field Methods. In *Springer International Publishing*. https://doi.org/10.1007/978-3-319-05633-3

[118] Murgoci, N. (2022a). Comparative study on the efficiency of motor rehabilitation of the lower limbs using a stationary horizontal bicycle versus a standard therapeutic program. *Balneo and PRM Research Journal*, *13*(4), 1–18. https://doi.org/10.12680/balneo.2022.524

[119] Murgoci, N. (2022b). The impact of perception regarding therapeutic exercises and dietary changing adherence of subjects known with low back pain. *Balneo and PRM Research Journal*, *13*(Vol.13, 4), 525. https://doi.org/10.12680/balneo.2022.525

[120] Murgoci, N. (2023). Quality of life outcomes evaluation after motor rehabilitation of the lower limbs using a stationary bicycle. *Balneo and PRM Research Journal*, *14*(1), 1–17. https://doi.org/10.12680/balneo.2023.533

[121] MURGOCI, N. (2021). The importance of body composition assessment in the rehabilitation process. *Balneo and PRM Research Journal*, *Vol.12*, *4*, 351–364.

https://doi.org/10.12680/balneo.2021.463
[122] Murgoci, N., & Mereuță, C. (2021). Aspects of the Importance of First Metatarsophalangeal Joint in the Process of Gait Recovery. *The Annals of "Dunarea de Jos" University of Galati Fascicle XV Physical Education and Sport Management*, *1*, 20–32. https://doi.org/10.35219/efms.2021.1.02
[123] Murgoci, N., Mereuţă, C., & Ganea, D. (2022). Gait facilitation program using a horizontal bicycle built and designed to monitor kinetic chain parameters – case study. *Annals of "Dunarea de Jos" University of Galati. Fascicle XV, Physical Education and Sport Management*, *Vol 1*, 63–78. https://doi.org/10.35219/efms.2022.1.05
[124] Murgoci, N., Mereuță, C., & Nanu, L. (2022). Dosage of Therapeutic Exercise According To Patients' Risk Chart Determined By Bioimpedance. *The Annals of "Dunarea de Jos" University of Galati Fascicle XV Physical Education and Sport Management*, *1*, 34–62. https://doi.org/10.35219/efms.2022.1.04
[125] Naci, H., & Ioannidis, J. P. A. (2015). Evaluation of wellness determinants and interventions by citizen scientists. *JAMA - Journal of the American Medical Association*, *314*(2), 121–122. https://doi.org/10.1001/jama.2015.6160
[126] Nader, G. A., & Lundberg, I. E. (2009). Exercise as an anti-inflammatory intervention to combat inflammatory diseases of muscle. *Current Opinion in Rheumatology*, *21*(6), 599–603. https://doi.org/10.1097/BOR.0b013e3283319d53
[127] Nickels, M. R., Aitken, L. M., Walsham, J., Barnett, A. G., & McPhail, S. M. (2017). Critical Care Cycling Study (CYCLIST) trial protocol: A randomised controlled trial of usual care plus additional in-bed cycling sessions versus usual care in the critically ill. *BMJ Open*, *7*(10). https://doi.org/10.1136/bmjopen-2017-017393
[128] O'Sullivan, S. B., Schmitz, T. J., & Fulk, G. (2019). Physical Rehabilitation. In *Philadelphia : F.A. Davis Company* (Sixth). F. A. Davis Company Copyright.
[129] Ohkoshi, Y., Yasuda, K., Kaneda, K., Wada, T., & Yamanaka, M. (1991). Biomechanical analysis of rehabilitation in the standing position. *The American Journal of Sports Medicine*, *19*(6), 605–611. https://doi.org/10.1177/036354659101900609
[130] orthotoolkit.com. (2022). *SF-36 -- OrthoToolKit*. OrthoToolKit. https://orthotoolkit.com/sf-36/
[131] P. Sarada, B. R. (2015). *Positive Stress and Its Impact on Performance.* Research Journal of Pharmaceutical, Biological and Chemical Sciences. https://www.semanticscholar.org/paper/Positive-Stress-and-Its-Impact-on-Performance.-Sarada-Ramkumar/45dbfbe0062a98409c9d4a0f2a089db4b89bcf47?sort=relevance&pdf=true
[132] Palmitier, R. A., An, K. N., Scott, S. G., & Chao, E. Y. S. (1991). Kinetic Chain Exercise in Knee Rehabilitation. *Sports Medicine (Auckland, N.Z.)*, *11*(6), 402–413. https://doi.org/10.2165/00007256-199111060-00005
[133] Paquette, M. R., Zhang, S., Milner, C. E., Fairbrother, J. T., & Reinbolt, J. A. (2014). Effects of increased step width on frontal plane knee biomechanics in healthy older adults during stair descent. *Knee*, *21*(4), 821–826. https://doi.org/10.1016/j.knee.2014.03.006
[134] Pedersen, B. K., Steensberg, A., Fischer, C., Keller, C., Keller, P., Plomgaard, P., Febbraio, M., & Saltin, B. (2003). Searching for the exercise factor: Is IL-6 a candidate? *Journal of Muscle Research and Cell Motility*, *24*(2–3), 113–119. https://doi.org/10.1023/A:1026070911202
[135] Petersen, A. M. W., & Pedersen, B. K. (2005). The anti-inflammatory effect of exercise. *Journal of Applied Physiology*, *98*(4), 1154–1162. https://doi.org/10.1152/japplphysiol.00164.2004
[136] physio-pedia.com. (2022). *Spondylolisthesis*. Physio-Pedia.Com. https://www.physio-pedia.com/Spondylolisthesis
[137] Physio-pedia.com. (2022). *Kinetic Chain*. Physio-Pedia.Com. https://www.physio-pedia.com/Kinetic_Chain
[138] Physiopedia. (2022). *36-Item Short Form Survey (SF-36)*. Physiopedia. https://www.physio-pedia.com/36-Item_Short_Form_Survey_(SF-36)
[139] Raasch, C. C., & Zajac, F. E. (1999). Locomotor strategy for pedaling: Muscle groups and biomechanical functions. *Journal of Neurophysiology*, *82*(2), 515–525. https://doi.org/10.1152/jn.1999.82.2.515

[140] rand.org. (2022). *36-Item Short Form Survey (SF-36)*. Rand.Org. https://www.rand.org/health-care/surveys_tools/mos/36-item-short-form.html

[141] Ranky, R. G., Sivak, M. L., Lewis, J. A., Gade, V. K., Deutsch, J. E., & Mavroidis, C. (2014). Modular mechatronic system for stationary bicycles interfaced with virtual environment for rehabilitation. *Journal of NeuroEngineering and Rehabilitation*, *11*(1), 1–16. https://doi.org/10.1186/1743-0003-11-93

[142] Renson, R. (2000). New insights into the biography and scientific background of Nicolas Dally (1795-1862), father of Kinesiology (1857). *Kinesiology*, *32*(1), 5–14. http://articles.sirc.ca/search.cfm?id=S-658352%5Cnhttp://search.ebscohost.com/login.aspx?direct=true&db=sph&AN=SPHS-658352&site=ehost-live&scope=site%5Cnhttp://articles.sirc.ca/search.cfm?id=S-658352 DP - EBSCOhost DB - sph

[143] Rhodes, R. E., Beauchamp, M. R., Blanchard, C. M., Bredin, S. S. D., Warburton, D. E. R., & Maddison, R. (2018). Use of in-home stationary cycling equipment among parents in a family-based randomized trial intervention. *Journal of Science and Medicine in Sport*, *21*(10), 1050–1056. https://doi.org/10.1016/j.jsams.2018.03.013

[144] Richard J. Johns, V. W. (1962). Relative importance of various tissues in joint stiffness. *Journal of Applied Physiology*, *17*(5), 824—828. https://doi.org/10.1152/jappl.1962.17.5.824

[145] Ringdal, M., Warren Stomberg, M., Egnell, K., Wennberg, E., Zätterman, R., & Rylander, C. (2018). In-bed cycling in the ICU; patient safety and recollections with motivational effects. *Acta Anaesthesiologica Scandinavica*, *62*(5), 658–665. https://doi.org/10.1111/aas.13070

[146] Rivas, D. A., & Fielding, R. A. (2013). Skeletal Muscle. *Encyclopedia of Human Nutrition*, *4–4*, 193–199. https://doi.org/10.1016/B978-0-12-375083-9.00188-4

[147] ro.wikipedia.org. (2022). *Sănătate*. Ro.Wikipedia.Org. https://ro.wikipedia.org/wiki/Sănătate

[148] Robofun.ro. (2021a). *Arduino UNO R3 (ATmega328p) - Placa de Dezvoltare Compatibila cu Arduino IDE + Cablu USB*. Robofun.Ro. https://www.optimusdigital.ro/ro/placi-avr/4561-placa-de-dezvoltare-compatibila-cu-arduino-uno-r3-atmega328p-atmega16u2-cablu-50-cm.html?search_query=arduino&results=568

[149] Robofun.ro. (2021b). *Banda de cupru cu adeziv - 6mm x 15 metri*. Robofun.Ro. https://www.robofun.ro/e-textil/banda-de-cupru-cu-adeziv-6mm-x-15-metri.html

[150] Robofun.ro. (2021c). *Fir Conexiune Multifilar 0.22 mm^2*. Robofun.Ro. https://www.robofun.ro/cabluri/fir-conexiune-multifilar-0-22-mm-2-albastru.html

[151] Rugs, D., Powell-Cope, G., Campo, M., Darragh, A., Harwood, K., Kuhn, J., & Rockefeller, K. (2020). The use of safe patient handling and mobility equipment in rehabilitation. *Work*, *66*(1), 31–40. https://doi.org/10.3233/WOR-203148

[152] Rupali Swain, S. K. (2020). *Rehabilitation Equipment Market Size By Product*. Global Market Insights. https://www.gminsights.com/industry-analysis/rehabilitation-equipment-market

[153] Scheffers, M. F., Ona Ayala, K. E., Ottesen, T. D., & Tuakli-Wosornu, Y. A. (2021). Design and development of mobility equipment for persons with disabilities in low-resource and tropical settings: bamboo wheelchairs. *Disability and Rehabilitation: Assistive Technology*, *16*(4), 377–383. https://doi.org/10.1080/17483107.2019.1695962

[154] Scherr, J., Wolfarth, B., Christle, J. W., Pressler, A., Wagenpfeil, S., & Halle, M. (2013). Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *European Journal of Applied Physiology*, *113*(1), 147–155. https://doi.org/10.1007/s00421-012-2421-x

[155] Seene, T., & Kaasik, P. (2012). Muscle weakness in the elderly: Role of sarcopenia, dynapenia, and possibilities for rehabilitation. *European Review of Aging and Physical Activity*, *9*(2), 109–117. https://doi.org/10.1007/s11556-012-0102-8

[156] Selye H. (1976). Stress without distress. Le stress sans detresse. *Bruxelles Medical*, *56*(5), 205–210. https://doi.org/10.1007/978-1-4684-2238-2_9

[157] Shadrin, I. Y., Khodabukus, A., & Bursac, N. (2016). Striated muscle function, regeneration, and repair. *Cellular and Molecular Life Sciences*, *73*(22), 4175–4202.

https://doi.org/10.1007/s00018-016-2285-z
[158] Shibata, S., Perhonen, M., & Levine, B. D. (2010). Supine cycling plus volume loading prevent cardiovascular deconditioning during bed rest. *Journal of Applied Physiology*, *108*(5), 1177–1186. https://doi.org/10.1152/japplphysiol.01408.2009
[159] Shirley Sahrmann. (2002). Diagnosis and Treatment of Movement Impairment Syndromes. In *Mosby, Inc.*
[160] Sigmanortec.ro. (2021). *Carcasa plastic transparent arduino uno*. Sigmanortec.Ro. https://www.sigmanortec.ro/Carcasa-plastic-transparent-Arduino-UNO-p190559674?gclid=EAIaIQobChMIqafK55qV9gIVluvtCh2zYQYpEAQYASABEgI4T_D_BwE
[161] Sporis, G., Badric, M., Prskalo, I., & Bonacin, D. (2013). Kinesiology - Systematic review. *Sport Science*, 7–23. https://www.researchgate.net/publication/258029579_Kinesiology_-_Systematic_review
[162] Sprigle, S., Chen, J., & Hughes, D. (2020). Assessment of wheeled mobility devices provided to a commercially insured population in 2017. *Assistive Technology*, *34*(3), 308–315. https://doi.org/10.1080/10400435.2020.1812765
[163] Sprigle, S., & Johnson Taylor, S. (2019). Data-mining analysis of the provision of mobility devices in the United States with emphasis on complex rehab technology. *Assistive Technology*, *31*(3), 141–146. https://doi.org/10.1080/10400435.2017.1402391
[164] Stepper-guide.com. (2020). *Are Mini Exercise Bikes Effective*. Stepper-Guide.Com. https://stepper-guide.com/are-mini-exercise-bikes-effective
[165] Stickel, M. S., Ryan, S., Rigby, P. J., & Jutai, J. W. (2002). Toward a comprehensive evaluation of the impact of electronic aids to daily living: Evaluation of consumer satisfaction. *Disability and Rehabilitation*, *24*(1–3), 115–125. https://doi.org/10.1080/09638280110066794
[166] Tabata, K, N., M, K., Y, H., F, O., M, M., & K., Y. (1996). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and · VO 2max. *Medicine & Science in Sports & Exercise*, *28*(October 1996), 1327–1330. https://doi.org/0.1097/00005768-199610000-00018
[167] Taft, C., Karlsson, J., & Sullivan, M. (2001). Do SF-36 summary component scores accurately summarize subscale scores? *Quality of Life Research*, *10*(5), 395–404. https://doi.org/10.1023/A:1012552211996
[168] Techfit.ro. (2021). *Pedalier TECHFIT cu afisaj*. Techfit.Ro. https://www.techfit.ro/biciclete-fitness.html/pedalier-cu-afisaj-techfit
[169] The Association of Faculties of Medicine of Canada. (2022). *AFMC Primer on Population Health Primer Contents, Part 1 - Theory: Thinking About Health Chapter 1 Concepts of Health and Illness, Definitions of Health*. AFMC Primer on Population Health. https://phprimer.afmc.ca/en/part-i/chapter-1/
[170] Thorsen, T. A. (2018). EFFECTS OF INCREASED Q-FACTOR ON KNEE BIOMECHANICS DURING CYCLING [University of Tennessee]. In *University of Tennessee*. https://trace.tennessee.edu/utk_gradthes/5111
[171] Tom Myers, H. C. (2018). *Building the Holistic Evidence Base – Facts and Fallacies*. Anatomy Trains. https://www.anatomytrains.com/blog/2018/04/02/building-holistic-evidence-base-facts-fallacies/
[172] Tudor Sbenghe. (2002). Kinesiologie Stiinta Miscarii. In *Editura Medicala*.
[173] United Nations Department of Economic and Social Affairs. (2019). World Population Ageing 2019. In *World population ageing 2019*. https://digitallibrary.un.org/record/3846855
[174] Valderrabano, V., & Easley, M. E. (2016). Foot and Ankle Sports Orthopaedics. In *Springer International Publishing Switzerland*. https://doi.org/10.1007/978-3-319-15735-1
[175] Vandewalle, H., & Driss, T. (2015). Friction-loaded cycle ergometers: Past, present and future. *Cogent Engineering*, *2*(1), 1–35. https://doi.org/10.1080/23311916.2015.1029237
[176] Verdonck, M. C., Chard, G., & Nolan, M. (2011). Electronic aids to daily living: Be able to do what you want. *Disability and Rehabilitation: Assistive Technology*, *6*(3), 268–281. https://doi.org/10.3109/17483107.2010.525291
[177] Viana, J. L., Kosmadakis, G. C., Watson, E. L., Bevington, A., Feehally, J., Bishop, N.

C., & Smith, A. C. (2014). Evidence for anti-inflammatory effects of exercise in CKD. *Journal of the American Society of Nephrology*, *25*(9). https://doi.org/10.1681/ASN.2013070702

[178] Victor Papilian. (2011). Anatomia Omului, Vol. 1 Aparatul Locomotor. *Editura ALL*.

[179] Walters, S. J. (2009). Quality of Life Outcomes in Clinical Trials and Health-Care Evaluation: A Practical Guide to Analysis and Interpretation. In *John Wiley & Sons, Ltd Registered*. https://doi.org/10.1002/9780470840481

[180] Walters, S. J., Morrell, C. J., & Dixon, S. (1999). Measuring health-related quality of life in patients with venous leg ulcers. *Quality of Life Research*, *8*(4), 327–336. https://doi.org/10.1023/A:1008992006845

[181] Walters, S. J., Munro, J. F., & Brazier, J. E. (2001). Using the SF-36 with older adults: A cross-sectional community-based survey. *Age and Ageing*, *30*(4), 337–343. https://doi.org/10.1093/ageing/30.4.337

[182] Ware, J. E. (2000a). SF-36 Health Survey update. *Spine*, *25*(24), 3130–3139. https://doi.org/10.1097/00007632-200012150-00008

[183] Ware, J. E. (2000b). SF-36 Health Survey Update. *Spine (Phila Pa 1976)*, *25*(24), 3130–3139. https://doi.org/10.1097/00007632-200012150-00008

[184] Ware JE Jr, S. C. (1992). 193 The MOS 36-Item Short-Form Health Survey (SF-36): I. Conceptual Framework and Item Selection. *Medical Care*, *30*(6), 473–483. https://www.jstor.org/stable/3765916

[185] Ware, John E., & Sherbourne, C. D. (1992). The MOS 36-item short-form health survey (Sf-36): I. conceptual framework and item selection. *Medical Care*, *30*(6), 473–483. https://doi.org/10.1097/00005650-199206000-00002

[186] Wattbike. (2022). *Functional Threshold Power (FTP) Training Zones*. Wattbike. https://support.wattbike.com/hc/en-gb/articles/115001848349-Functional-Threshold-Power-FTP-Training-Zones

[187] Webshop.mam-bricolaj.ro. (2021). *Profil aluminiu patrat 40x40 3m alb*. Webshop.Mam-Bricolaj.Ro. https://webshop.mam-bricolaj.ro/produs/profil-aluminiu-patrat-40x40-3m-alb

[188] Wert, D. M., Brach, J., Perera, S., & VanSwearingen, J. M. (2010). Gait biomechanics, spatial and temporal characteristics, and the energy cost of walking in older adults with impaired mobility. *Physical Therapy*, *90*(7), 977–985. https://doi.org/10.2522/ptj.20090316

[189] Wilk, K. E., Escamilla, R. F., Fleisig, G. S., Barrentine, S. W., Andrews, J. R., & Boyd, M. L. (1996). A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *The American Journal of Sports Medicine*, *24*(4), 518–527. https://doi.org/10.1177/036354659602400418

[190] Williams, A., Kamper, S. J., Wiggers, J. H., O'Brien, K. M., Lee, H., Wolfenden, L., Yoong, S. L., Robson, E., McAuley, J. H., Hartvigsen, J., & Williams, C. M. (2018). Musculoskeletal conditions may increase the risk of chronic disease: A systematic review and meta-analysis of cohort studies. *BMC Medicine*, *16*(1), 1–9. https://doi.org/10.1186/s12916-018-1151-2

[191] Wood, R. (2010). *Heart Rate Karvonen Formula*. Topend Sports Website. https://www.topendsports.com/fitness/karvonen-formula.htm

[192] World Health Organization. (2021). Rehabilitation needs of people recovering from COVID-19. In *World Health Organization* (Issue November). https://www.who.int/publications/i/item/WHO-2019-nCoV-Sci-Brief-Rehabilitation-2021.1

[193] World Health Organization. (2022). *Musculoskeletal health*. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions

[194] worldometers.info. (2023). *COVID-19 Coronavirus Pandemic*. Worldometers.Info. https://www.worldometers.info/coronavirus/

[195] Wroblewski, A. P., Amati, F., Smiley, M. A., Goodpaster, B., & Wright, V. (2011). Chronic exercise preserves lean muscle mass in masters athletes. *Physician and Sportsmedicine*, *39*(3), 172–178. https://doi.org/10.3810/psm.2011.09.1933

[196] Yang, Y. Z. J. S. Z.-T. L. C. X. Z. (2021). *Implementation of Impedance Control for Lower-Limb Rehabilitation Robots*. 2021 4th IEEE International Conference on Industrial Cyber-Physical Systems (ICPS). https://doi.org/10.1109/ICPS49255.2021.9468210

[197] Yocum, D., Weinhandl, J. T., Fairbrother, J. T., & Zhang, S. (2018). Wide step width

reduces knee abduction moment of obese adults during stair negotiation. *Journal of Biomechanics*, *75*, 138–146. https://doi.org/10.1016/j.jbiomech.2018.05.002

[198] Zhu, Y., Wang, Z., Zhou, Y., Onoda, K., Maruyama, H., Hu, C., & Liu, Z. (2020). Summary of respiratory rehabilitation and physical therapy guidelines for patients with COVID-19 based on recommendations of World Confederation for Physical Therapy and National Association of Physical Therapy. *Journal of Physical Therapy Science*, *32*(8), 545–549. https://doi.org/10.1589/jpts.32.545