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Research article

Comparative study on the efficiency of motor rehabilitation of the lower limbs using a stationary horizontal bicycle versus a standard therapeutic program

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Abstract: The purpose of the present study is to compare the efficiency of two physiotherapeutic programs for rehabilitation of the lower limbs, one using a stationary bicycle and the other one being a standard program, targeting muscle imbalance deficit. Subjects are outpatients - the control group (C n=5), 58.67 ± 11.67 years, received a standard rehabilitation program, and the experimental group (E n=5), 56.67 ± 12.14 years, received a proposed rehabilitation program implying a stationary bicycle. Equipment used is for muscle imbalances – sensor attached to bicycle pedals, for joint testing – goniometer, for heart rate smart watch, pain assessment – VAS numeric scale, and for perceived effort Borg scale. The rehabilitation program including the stationary horizontal bicycle obtained better results in terms of pain control (T-Test p C/E=.004/.001 and Wilcoxon p C/E=.039/.041) and the correction of muscular imbalances (T-Test p C/E=.003/.000, r= .990/.997) related to the lower limbs, with the mention that both programs recorded statistically significant results regarding functionality. HR values for the control group and experimental group < THR values, aerobic conditioning with the submaximal effort being essential for rehabilitation. Both programs maintained the same perceived level of effort with an average of 3.6 Borg- moderate effort, respectively mild-moderate dyspnea.

Keywords: rehabilitation; lower limbs; stationary bicycle; muscle imbalance; pedal sensor; analog value; heart rate (HR); target heart rate (THR).

1. Introduction

The purpose of the present study is to compare the efficiency of two physiotherapeutic programs for rehabilitation of the lower limbs, one using a stationary bicycle. Addresses are outpatients who are in the therapeutic window of intervention, with gait difficulties and have a medical indication for home kinetoterapy. This particular intervention focuses on kinetic chain analysis of lower limbs affected by musculoskeletal pathologies. Biomechanical deficit determined by the decreasing range of motion, strength, resistance, or motor control can be a barrier to gait facilitation. This approach implying a stationary bicycle targets muscle imbalance deficit that means loss of stabilizing capacity from agonists or antagonists [1]. Therapeutic exercise is the basis of physical therapy being an intervention that distinguishes it from other areas of health progress being continuous. Graded exercise therapy was developed for chronic fatigue syndrome based on patient deconditioning and poor exercise tolerance. Pedaling involves functional strengthening, posture, and body mechanics training [2]. Stationary cycling is classified as a low-impact activity. It allows patients to improve neuro-motor function, facilitates rehabilitation from conditions that disrupt the movement and activity of daily life, or maintains well-being through neuro-reeducation, reducing the risk of associated comorbidities. To prevent deficiencies, stationary cycling is used to optimize overall health [3].

This approach intends to be a parallel between two therapeutic interventions that address the entire chain of motion to restore the patient's proper motor function.

2. Materials and Methods

Participants

In the research, ten subjects were included who signed the informed consent form, through which they expressed their agreement regarding the conditions of participation in this scientific endeavor. Outpatients presented with a physiotherapy indication for gait rehabilitation from the specialist physician (including criteria). The research was carried out at the patient's homes following the medical credentials of the practice cabinet for physiotherapy. Exclusion criteria: any acute, infectious disease, cardiovascular disease, decompensated renal disease, or any life-threatening situation (acute pulmonary edema, pulmonary embolism, aortic dissection, craniocerebral trauma, acute myocardial infarction). The control group consists of five subjects out of which three men and two women, mean age of 58.67 ± 11.67. The experimental group comprises five subjects out of which three women and two men, mean age of 56.67 ± 12.14. The physiotherapy program was applied for four weeks for each patient during April 2022-September 2022.

Equipment

Equipment used for joint testing – goniometer, for muscle imbalances – sensor attached to Techfit PED2 pedals, for heart rate Smartwatch Huawei Watch GT 2, VAS for pain assessment, Borg scale for perceived effort, and Karvonen formula for THR.

Stationary horizontal recovery bike based on the model Techfit PED2 with 5 levels of intensity, recommended for people who lead a sedentary lifestyle as well as for elderly people with reduced mobility; due to its functionality, it can also be used by people with disabilities. I selected this pedaling system because the self-selected Q factor is established at 14 cm which reduces the risk of knee injury and provides increased efficiency while pedaling [4–7]. The horizontal bike was adapted and stabilized for bed use and endowed with plantar pressure sensors attached to the pedals to monitor outputs. The sensors attached to the pedals support a maximum load of 123 kg each according to the tests carried out in orthostatic posture with a load on healthy subjects, sensors considered viable in the conditions where the heaviest patient recorded 104 kg. The sensor signals attached to the pedals are converted to analog values for both feet by the mean of an Arduino board. Pressure sensors determine kinetic, biomechanical, and postural alignment chain imbalances. During a pre-test, a mild-moderate intensity was established, which was then set for all the participants according to their aerobic tolerance. Computer software, using C# language read the analog values and Data Steamer registered in Microsoft Excel for analysis. The application was run on an HP Compaq PresarioCQ81 laptop. Mean analog values (VAM) were computed for each lower limb and the difference was used to enhance the muscle imbalance.

Measures

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 to be included in the inclusion or exclusion criteria in the study;
- Information about the experimental study, obtaining consent for the application of the standard and proposed physical therapy programs involving the static horizontal pedal board;
- Application of the visual analog pain scale – numerical association (VAS);
- Joint balance - evaluation of the range of motion in the ankle, knee, and hip joints by goniometry;

- Muscular imbalances – assessment 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;

- Heart rate reserve as well as heart rate training - 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.

Procedure

The patients were introduced into the rehabilitation program immediately after discharge at home.

The control group and the experimental group included five subjects each, and to preserve the homogeneity of the study, 10 patients with similar basic impairments were selected from 27 patients to respect the principle of data comparability. Each group contains one patient with coxofemoral joint injury (coxarthrosis), one patient with stroke (hemiplegia/hemiparesis), one patient with knee joint injury (gonarthrosis), and two patients with ankle joint injury (post fracture/ sprain) and associated comorbidities hypertension, dyslipidemia, lumbosciatica. All patients included in the study had a mild to moderate episode of COVID-19 in antecedents that did not require hospitalization or oxygen therapy.

The rehabilitation program – initial stage, lasted 4 weeks with a frequency of 3 times a week, in a total of 12 sessions (50 min/session). Individual-specific exercises implied 5-7-10 reps. – progressive increasing at every four sessions for the control group. For the experimental group at every four sessions, a progressive level of pedaling intensity was implemented.

For the control group a standard rehabilitation program was applied taking into account the main pathology:

- Coxarthrosis, gonarthrosis associated with lumbosciatica (2 subjects) - 50 min/session detailed as therapeutic massage 15 min, inverted posture exercises 5 min, specific exercises (progressive Williams) 20 min, manual therapy and stretching 10 min;
- Stroke and hemiplegia (1 subject)- 50 min/session detailed as therapeutic massage 15 min, posture exercises 5 min, proprioceptive neuromuscular facilitation - Kabat – 10 min, passive, passive-active physical therapy -10 min, manual therapy and stretching 10 min;
- Post fracture/ sprain (2 subjects) - manual lymphatic drainage 15 min, proprioceptive neuromuscular facilitation - Kabat – 5 min, passive, passive-active physical therapy – 20 min, manual therapy and stretching 10 min.

For the experimental group a proposed rehabilitation program including a stationary bike was applied taking into account the main pathology:

- Coxarthrosis associated with lumbosciatica, moderate cardiovascular risk (1 subject) - 50 min/session detailed as therapeutic massage 5 min, posture exercises 4 min, static horizontal pedaling 31 min, manual therapy and stretching 10 min;
- Gonarthrosis associated with lumbosciatica, low cardiovascular risk (1 subject) - 50 min/session, detailed as therapeutic massage 5 min, posture exercises 5 min, static horizontal pedaling 35 min, manual therapy and stretching 5 min;
- Stroke and hemiparesis, moderate cardiovascular risk (1 subject)- 50 min/session detailed as therapeutic massage 5 min, static horizontal pedaling 31 min, posture exercises 4 min, manual therapy and stretching 10 min;
- Post fracture/ sprain, high cardiovascular risk (1 subject) - manual lymphatic drainage 8 min, static horizontal pedaling 27 min, neuro proprioceptive facilitation- Kabat 5 min, manual therapy and stretching 10 min;
- Post fracture/ sprain, moderate cardiovascular risk (1 subject) - manual lymphatic drainage 4 min, static horizontal pedaling 31 min, proprioceptive facilitation- Kabat 5 min, manual therapy and stretching 10 min;

Static horizontal pedaling for 27, 31, or 35 minutes implied a protocol accordingly to risk association. Timing details are in the following order: warm-up at baseline cycling intensity level 3 min, passive pause 3 min, fast pedaling 6/8/10 min, passive pause 3 min, easy pedaling 6/8/10 min, passive pause 3 min, cool down at baseline cycling intensity 3 min.

Pause integration keeps organism homeostasis and program adherence [8–10].

Statistical analyses

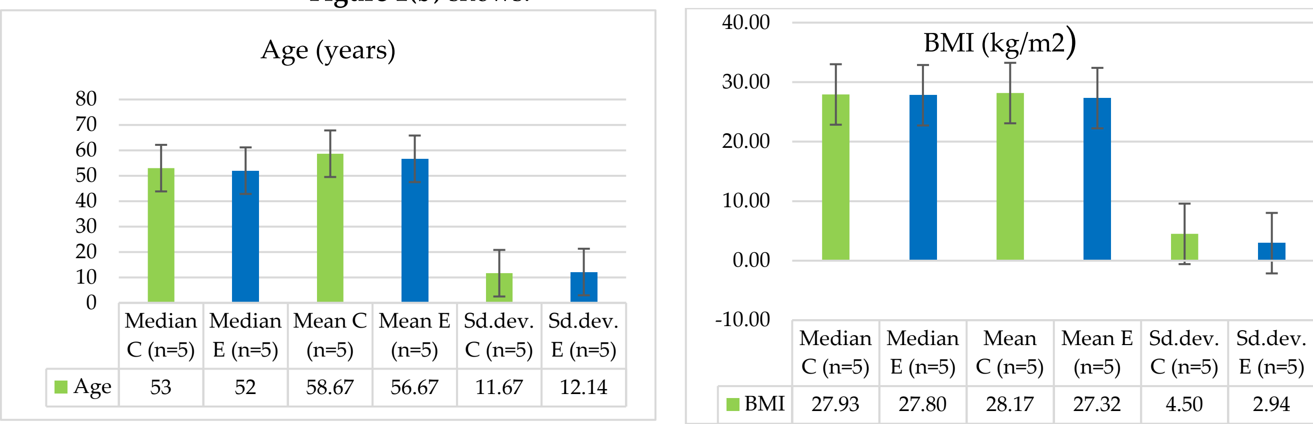
All statistical analyses were performed using SPSS version 25 and Microsoft Excel for data collection. Analysis with paired samples t-test and Wilcoxon was used to assess the differences within subjects and between participants and for statistical significance.

3. Results

The control group and the experimental group included five subjects each.

3.1. **General characteristics** related to the control group (C) and the experimental group (E). The selected groups are relatively homogeneous from the point of view of age, height, weight, and body mass index.

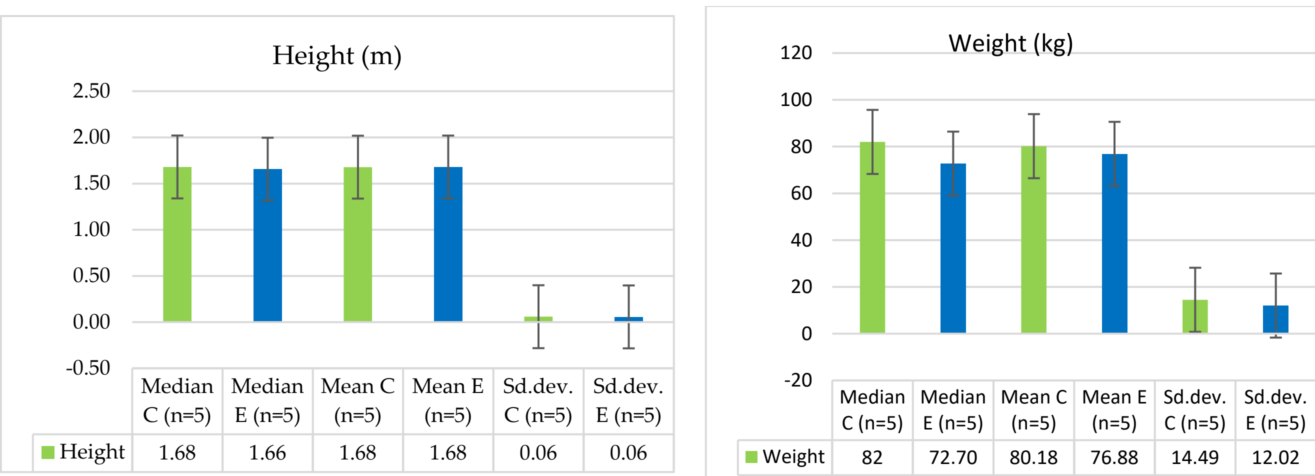
The control group recorded a mean age of 58.67±11.67 years, a median of 53 years *versus* the experimental group's mean age of 56.67±12.14 years, a median of 52 years as **Figure 1(a)** shows. BMI (kg/m²) for the control group registered a mean of 28.17±4.50, a median of 27.93 *versus* the experimental group's mean of 27.32±2.94, a median of 27.80 as **Figure 1(b)** shows.



(**a**) (**b**)

Figure 1. (**a**) Age (years); (**b**) BMI (kg/m²)

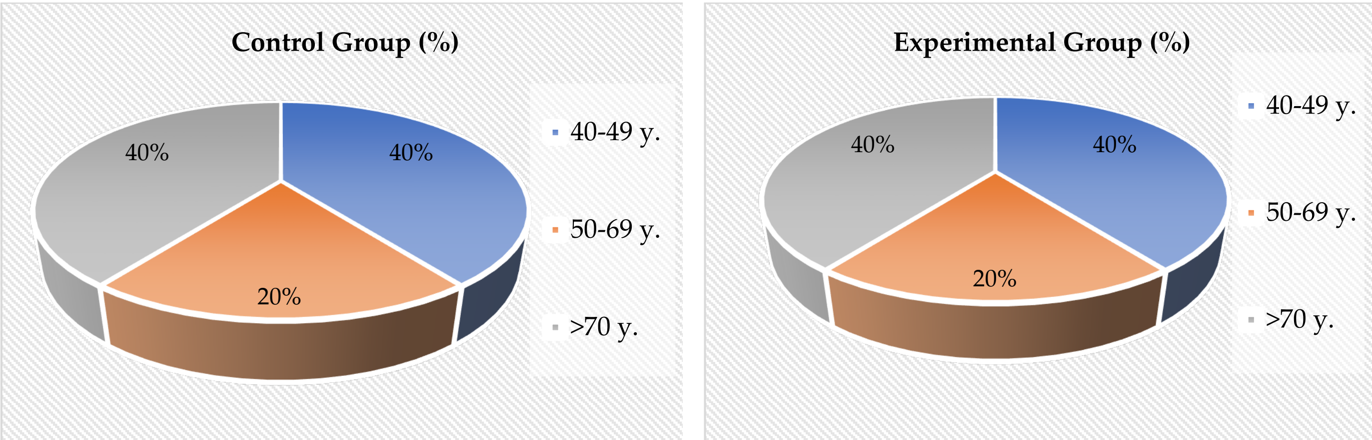
Measures regarding height are for the control group mean 1.68±0.06, median 1.68 m and for the experimental group 1.68±0.06, median 1.66 m as **Figure 2(a)** shows. Weight for the control group registered a mean of 80.18±14.49, with a median of 82 (kg) and for the experimental group registered a mean of 76.88±12.02, a median of 72.70 (kg) as **Figure 2(b)** shows.



(**a**) (**b**)

Figure 2. (**a**) Height(m); (**b**) Weight (kg)

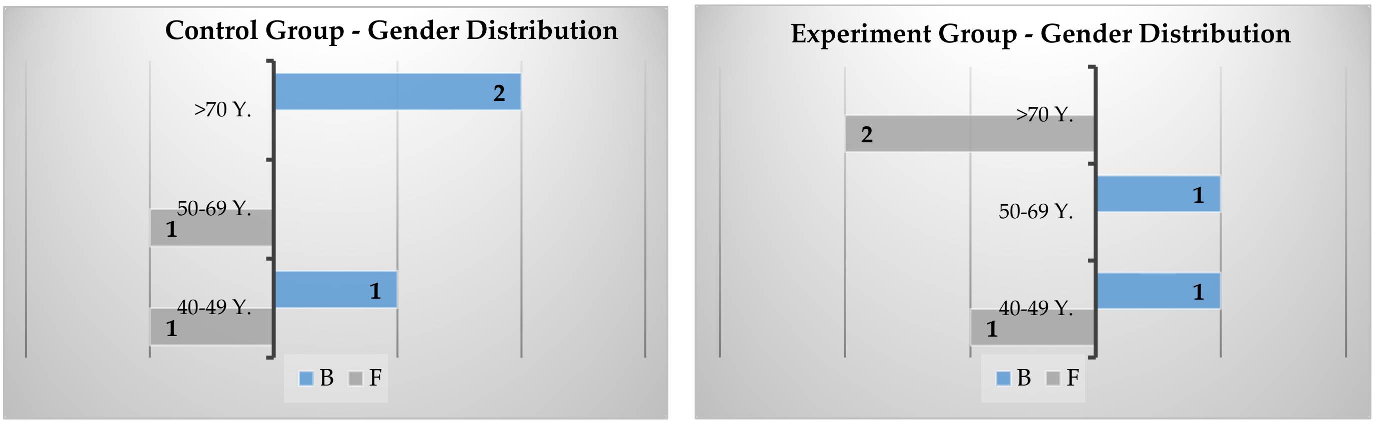
Three age groups 40-49 years, 50-69 years, and>70 years were established according to the rate of muscle loss, due to the variability of muscle mass with aging which decreases with age. By age 40 are peak levels, and between age 40 and 50 and beyond, the loss of lower limb muscle mass is 1-2% per year, and the loss of strength levels is 1.5-5% per year [11,12]. Both groups have a similar age structure 2 subjects -40% 40-49 y, one subject - 20% 50-69 y, and two subjects – 40% over 70y. (**Figure 3 a,b**).



(**a**) (**b**)

Figure 3. Age Structure (**a**) Control Group; (**b**) Experimental Group

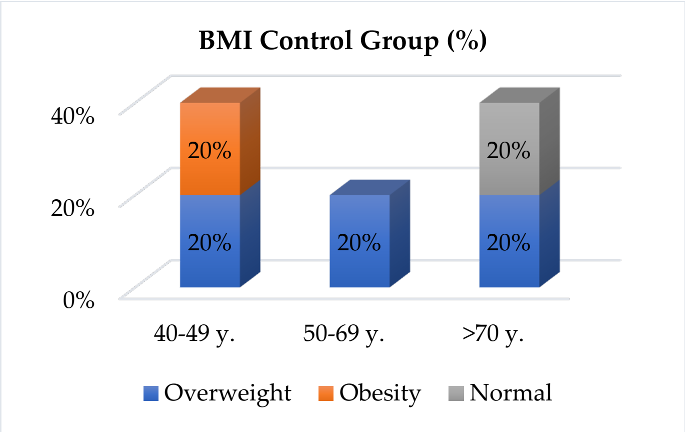
The control group according to gender includes two women -40% (one subject belonging to the group 40-49 years old and one subject belonging to the group 50-69 years old) and three men - 60% (one subject belonging to the group 40-49 years old and two subjects >70 years). The experimental group according 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 4 a,b**).



(**a**) (**b**)

Figure 4. (**a**) Control Group - Gender Distribution; (**b**) Experiment Group - Gender Distribution

BMI of the control group: 20% of the subjects have a normal weight (one subject >70 years), 60% are overweight (one subject belonging to the 40-49 years group, one subject belonging to the 50-69 years group and one subject >70 years) and 20% obese (a subject belonging to the 40-49 years group). BMI of the experimental group: 20% of the subjects have a 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 year group). (**Figure 5 a,b**)



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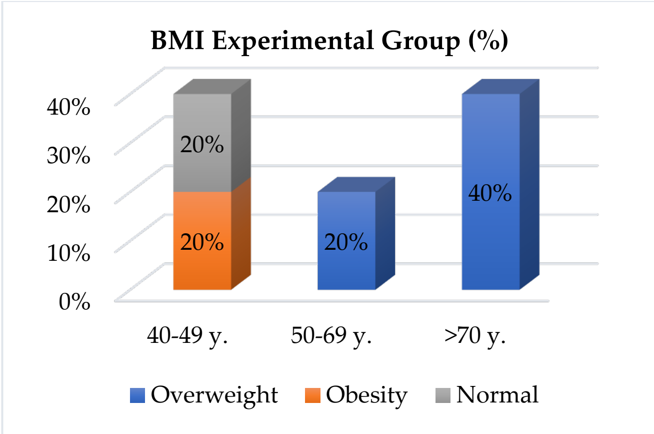


(**b**)

Figure 5. (**a**) BMI Control Group (%); (**b**) BMI Experimental Group (%)

3.2. Outputs

3.2.1. Pain Assessment - VAS Analyze

The visual analog scale VAS = (0-10) evaluates the intensity of the pain that the patient complains of being a simple, valid, and effective tool to evaluate the control of the disease. The interpretation of the results by numerical association allows the possibility of conducting statistics studies so the interpretation of the results respected the following standardization: 0- no pain, 1-3 mild pain, 4-7 moderate pain, and 8-10 severe pain [13,14].

The z-test for a single sample, in our case the control group and the experimental group, is used to test the difference between the mean of a sample and the known mean of the population of which it is a part.

Table 1. Z(T) for VAS means of the control group (C) and experimental group (E) at T0

T0 VAS Analyze	**The parametric test z (t) for VAS mean of groups(95% CI)**		
Pain Assessment	mean±st.dev.(1.140)	test z (t)	sig.
C	5.6	10.983	0.000
E	5.4	10.590	0.000

T0 = before starting the standard physical therapy program for the control group (C) and before starting the proposed physical therapy program with the horizontal pedal board for the experimental group (E).

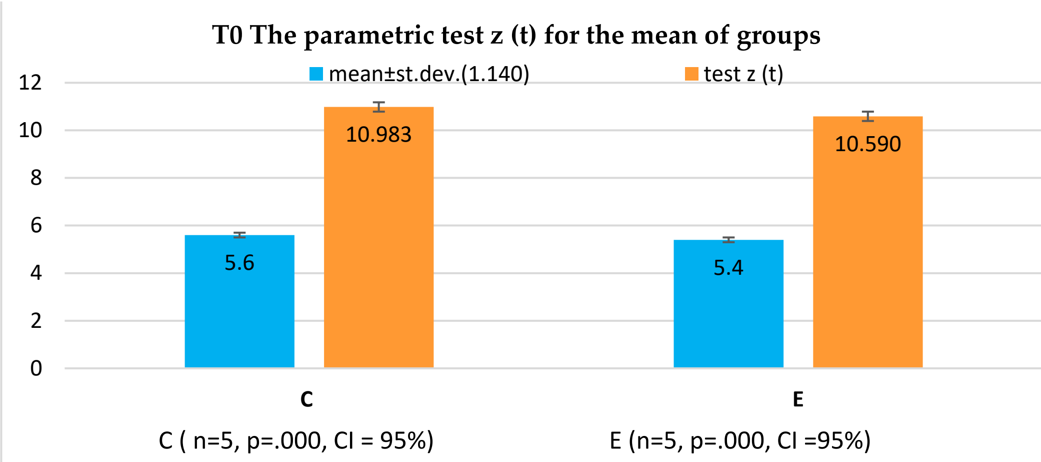


Figure 6. The parametric test z (t) for the mean of groups at T0

The conclusion of the z-test – C z(t) =10.983, E z(t) =10.590, applied to both groups shows that the mean of the research sample C (5.6±1.140) and E(5.4±1.140) differs significantly from the mean of the standard population (p=.000, CI =95%) **as Table 1 and Figure 6** shows.

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.

Table 2. The T-test for paired samples applied to VAS "before" and "after" the recovery program

Paired Samples Test applied to VAS "before" and "after" the recovery program								
	Paired Differences							
				95% Confidence Interval of the Difference				
VAS T0 – VAS T1	Mean (m)	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	p
C [mT1 (5.60) - mT0 (3.40)]	2.200	0.837	0.374	1.161	3.239	5.880	4	0.004
E [mT1 (5.40) - mT0 (2.00)]	3.400	0.894	0.400	2.289	4.511	8.500	4	0.001

We are interested in whether the experimental recovery program affects pain perception (VAS).

Hypothesis H0: There is no effect of the standard/experimental

Hypothesis H1: There is a therapeutic effect of the standard/experimental program

The observed difference between the means (m) is C 2.2/ E 3.4 proves there is an effect of the experimental recovery program on the experimental group

Since the T-test value is t(C)= 5.880 (p=.004) and t(E)= 8.550 (p=.001) threshold, the 2.2/3.4 difference between the means (m) of the pretest and posttest variables is statistically significant. (**Table 2**)

Thus, at a significance threshold (p) C/E of.004/.001, the null hypothesis is rejected. It can be considered that there is an effect of the recovery programs for both groups.

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 7**)

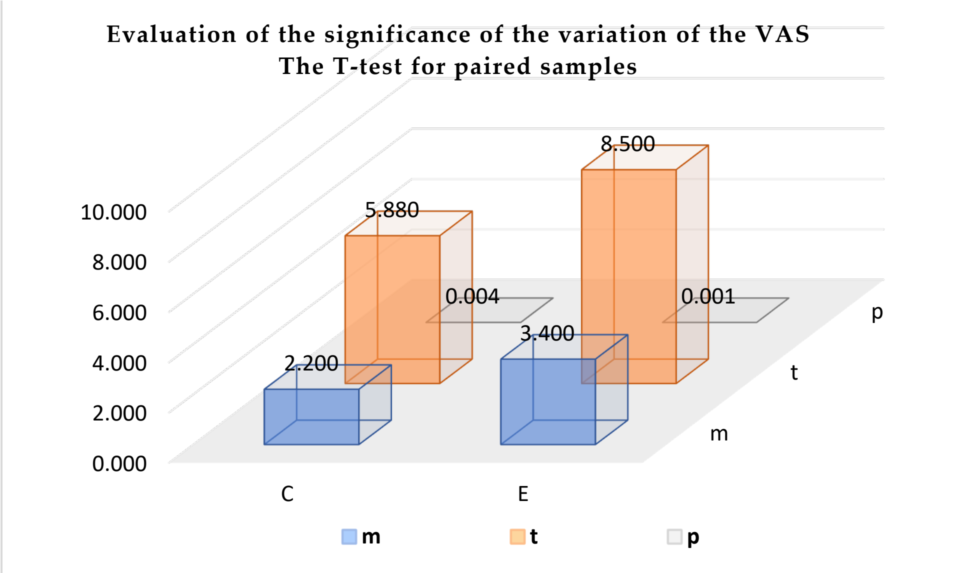


Figure 7. Evaluation of the significance of the variation of the VAS

The Wilcoxon test is used to test the difference between values, using the sign of the difference, when both values are measured for the same subjects.

At T1, pain perception registered a decrease after applying the standard and proposed physical therapy programs.

The control group vs. the related experimental group shows $p<0.05$, with greater significance for the experimental group p=.039 vs. p=.041 relative to the control group as Table 3 and Figure 8 show.

Table 3. Wilcoxon Test Statistics - VAS

	Wilcoxon Test Statistics VAS	
	C(VAS T1 - VAS T0)	**E(VAS T1 - VAS T0)**
Z	-2.041	-2.060
p	**0.041**	**0.039**

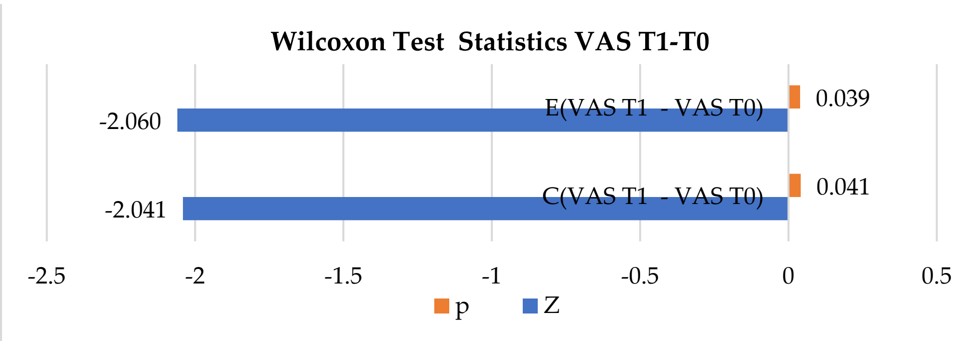


Figure 8. Wilcoxon Test Statistics VAS T1-T0

3.2.2. Joint testing (JT)

The joint balance included the evaluation by goniometry before (T0) and after (T1) of the performance of the physiotherapy programs of the hip (flexion), of the knee (flexion), and of the ankle (total amplitude) and highlighting the key joint involved in facilitating ambulation depending on the related pathologies of each patient. The reference was the optimal value of the articular amplitude defined as the target [15].

The descriptive statistics highlight the value to be recovered until reaching the therapeutic target. (**Table 4, Figure 9a**)

- For the control group the decrease in the recoverable value of the joint amplitude with an average of 24 degrees at the end of the sessions compared to 37 degrees initially and a median of 19 degrees at the end of the sessions compared to 31 degrees initially;
- For the experimental group the decrease in the recoverable value of the joint amplitude with an average of 24.80 degrees at the end of the sessions compared to 45.80 degrees initially and a median of 14 degrees at the end of the sessions compared to 38 degrees initially.

Table 4. Wilcoxon test for two paired samples for joint balance

Wilcoxon Descriptive Statistics Joint Testing								
						Percentiles		
	N	Mean	Std. Deviation	Minimum	Maximum	25th	50th (Median)	75th
Initial C	5	37.00	14.071	24	60	27.00	31.00	50.00
Final C	5	24.00	14.071	10	45	12.50	19.00	38.00
Initial E	5	45.80	19.280	35	80	35.00	38.00	60.50
Final E	5	24.80	22.687	12	65	12.50	14.00	42.50

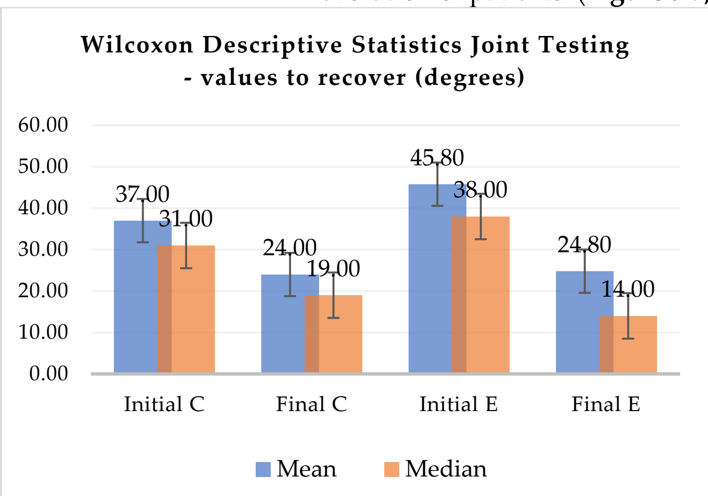
The Wilcoxon test analysis for joint balance is performed on the subjects belonging to the control and experimental group.

Table 5. Wilcoxon Test Statistics JT

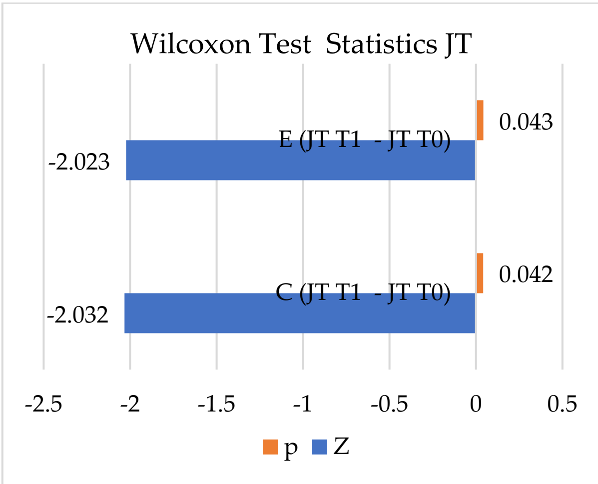
Wilcoxon Test Statistics JT		
	C (JT T1 - JT T0)	E (JT T1 - JT T0)
Z	-2.032	-2.023
p	0.042	0.043

Both physical therapy programs applied to groups (C/E) of independent patients reveal statistical significance (p<.05) C p=.042, E p=.043 (**Table 5, Figure 9b**)

The analyzed variable is the injured joint and the value to be recovered until reaching the therapeutic target, values measured by goniometry expressed in degrees as mean and median for control and experimental groups have a decreasing trend, a sign of a favorable evolution of patients. (**Figure 9 a,b**).



(a)



(b)

Figure 9. Wilcoxon Test - JT

The t-test of the difference of the means of two dependent samples allows the evaluation of the significance of the variation of the movement amplitude, in the same subjects, in two different situations "before" and "after" the application of the rehabilitation program. The major advantage of this statistical model is that it captures the so-called "intra-subject" variation, in that the basis of calculation is the difference between two values measured for each subject. The values are in degrees obtained by goniometry for hip and knee flexion and ankle ROM. We are interested in whether physical therapy programs affect joint mobility. Negative means reveal gain in amplitude, reference moment being T0.

Hypothesis H0: There is no effect of the physical therapy programs.

Hypothesis H1: There is an effect of physical therapy programs.

Table 6. The t-test of the difference between the means of the control group (C) and experimental group (E)

T Test Paired Samples Statistics JT					
		Mean (m)	N	Std. Deviation	Std. Error Mean
C	JT T0	50.00	5	17.762	7.944
	JT T1	63.00	5	20.012	8.950
E	JT T0	41.20	5	12.775	5.713
	JT T1	62.20	5	11.454	5.122

Table 7. T – Test Paired Differences - JT

		T – Test Paired Differences					t	df	Sig. (2-tailed)
		Mean (m)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
C	JT T0 (50) – JT T1 (63)	-13.000	2.550	1.140	-16.166	-9.834	-11.402	4	0.000
E	JT T0 (41.20) – JT T1 (62.20)	-21.000	4.637	2.074	-26.757	-15.243	-10.127	4	0.001

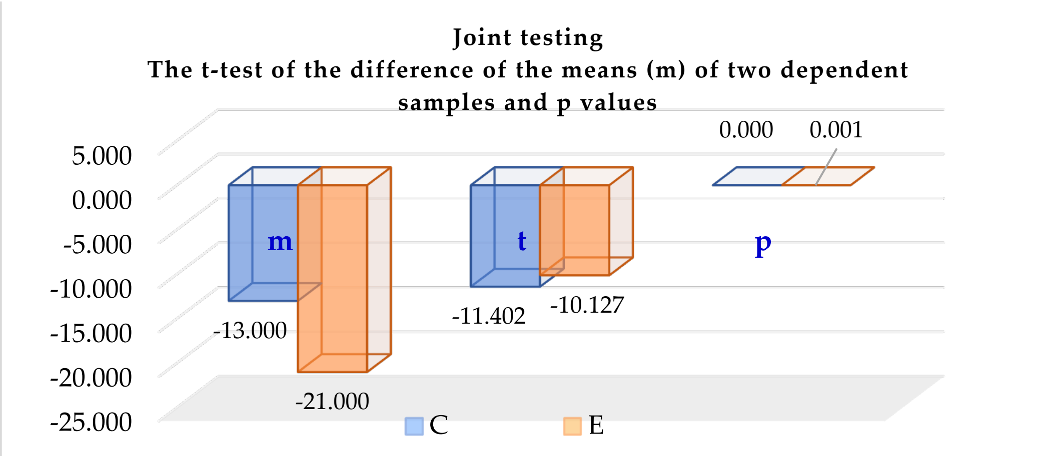


Figure 10. T – Test Paired Differences - JT

The standard physical therapy program affects joint mobility. According to **Tables 6 and 7**, the observed difference between the averages is -13 degrees. Since the value of the T-test is t=-11.402 for the p=.000 threshold, the difference of -13 degrees between the averages of the JT T0 and JT T1 variables is statistically significant. Thus, at a significance threshold of 0.000 (CI =95%), the null hypothesis is rejected. (**Figure 10**)

The proposed physical therapy program affects joint mobility. According to **Tables 6 and 7**, the observed difference between the averages is -21. Since the value of the T-test is t=-10.127 for the p=.001 threshold, the difference of -21 between the averages of the JT T0 and JT T1 variables is statistically significant. Thus, at a significance threshold of 0.001 (CI =95%), the null hypothesis is rejected. (**Figure 10**)

It can be considered that there is an effect of the proposed rehabilitation program on the improvement of the joint balance values similar for both groups.

3.2.3. Muscle Imbalances

T-test Paired differences were used for muscle imbalance. VAM average analog values were calculated as differences between the lower limbs. We are interested in whether the standard physical therapy program affects muscle imbalances related to the lower limbs, measured as a difference in analogic value between the left and right lower limbs.

Hypothesis H0: There is no effect of the physical therapy programs on muscle imbalances for both groups

Hypothesis H1: There is an effect of the physical therapy programs on muscle imbalances on muscle imbalances for both groups.

Descriptive statistics with dependent paired samples for the control group identified a decrease in muscle imbalance related to the lower limbs at 28.40 VAM after performing the standard physiotherapy program compared to 48 degrees before the start of the therapy according to **Table 8**, the correlation index being 0.990, statistically significant p< 0.05 (.001) according to **Table 9**. The observed difference between the averages is 19.6 (**Tables 8 and 10**). Since the value of the T-test is t=6.441 for the threshold p = .003, the difference of 19.6 between the means of the VAM T0 and VAM T1 variables is statistically significant. Thus, at a significance threshold of 0.003, the null hypothesis is rejected for the control group.

Descriptive statistics dependent paired samples - the experimental group identified a decrease in the afferent muscular imbalance of the lower limbs at 24.40 VAM after performing the standard physiotherapy program compared to 49.60 degrees before the start of the therapy according to **Table 8**, the correlation index being 0.997, statistically significant p< 0.05 (.000) according to **Table 9**. The observed difference between the averages is 25.2 (**Tables 8 and 10**). Since the value of the T-test is t=12.096 for the threshold p < 0.05 (.000), the difference of 25.2 between the means of the variables VAM T0 and VAM T1 is statistically significant. Thus, at a significance threshold of 0.000, the null hypothesis is rejected.

Table 8. T-test Paired Samples Statistics VAM

T-test Paired Samples Statistics VAM					
		Mean	N	Std. Deviation	Std. Error Mean
C	Dif VAM T0	48.00	5	23.108	10.334
	Dif VAM T1	28.40	5	16.891	7.554
E	Dif VAM T0	49.60	5	32.631	14.593
	Dif VAM T1	24.40	5	28.553	12.769

Table 9. Paired Samples Correlations (r) VAM

Paired Samples Correlations (r)				
		N	Correlation	Sig.
C	Dif VAM T0 & Dif VAM T1	5	0.990	0.001
E	Dif VAM T0 & Dif VAM T1	5	0.997	0.000

Table 10. Paired Differences- T-test - VAM

Paired Differences T-test- VAM									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% CI of the Difference Lower	95% CI of the Difference Upper			
C	Dif VAM T0 (48) - Dif VAM T1 (28.40)	19.600	6.804	3.043	11.151	28.049	6.441	4	0.003
E	Dif VAM T0 (49.60) - Dif VAM T1 (24.40)	25.200	4.658	2.083	19.416	30.984	12.096	4	0.000

It can be considered that there is an effect of the proposed rehabilitation program on improving the values of muscular imbalances related to the lower limbs that is better than the standard. E p =.000; C p =.003 (**Table 10** and **Figure 11**)

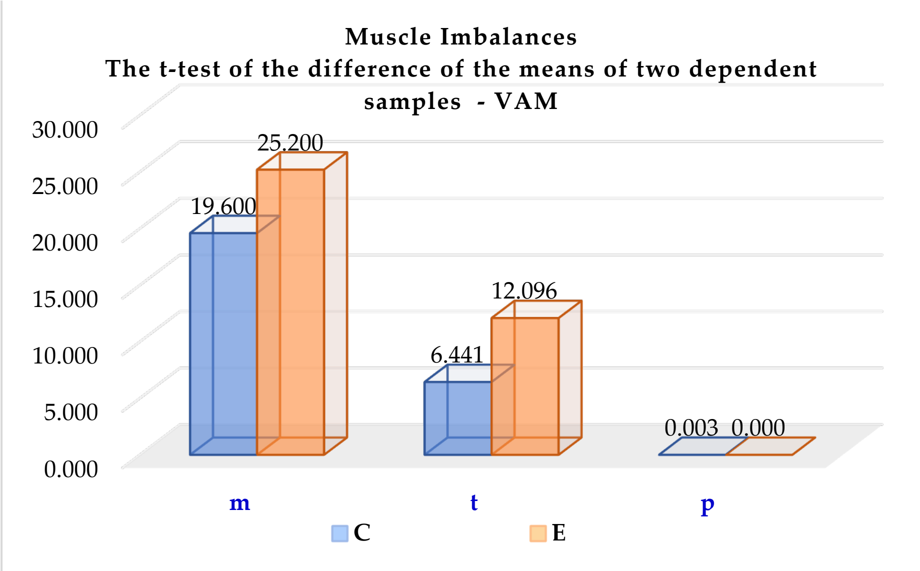


Figure 11. Muscle imbalance T-Test of the difference of means – dependent samples –VAM

Wilcoxon Test descriptive statistics **for the control group** highlight the decrease in the value of muscle imbalances with an average of 28.40 at the end of the sessions compared to 48 initially and a median of 25 at the end of the sessions compared to 42 initially. (**Table 11** and **Figure 12**)

Wilcoxon Test descriptive statistics **for the experimental** group highlight the decrease in the value of muscle imbalances with an average of 24.40 at the end of the sessions compared to 49.60 initially and a median of 12 at the end of the sessions compared to 39 initially. (**Table 11** and **Figure 12**)

Table 11. Wilcoxon Descriptive Statistics Muscle Imbalances

Wilcoxon Descriptive Statistics Muscle Imbalances								
						Percentiles		
	N	Mean	Std. Deviation	Minimum	Maximum	25th	50th (Median)	75th
Dif VAM T0 C	5	**48.00**	23.108	26	84	29.00	**42.00**	70.00
Dif VAM T1 C	5	**28.40**	16.891	10	55	15.00	**25.00**	43.50
Dif VAM T0 E	5	**49.60**	32.631	29	107	29.50	**39.00**	75.00
Dif VAM T1 E	5	**24.40**	28.553	8	75	8.50	**12.00**	46.50

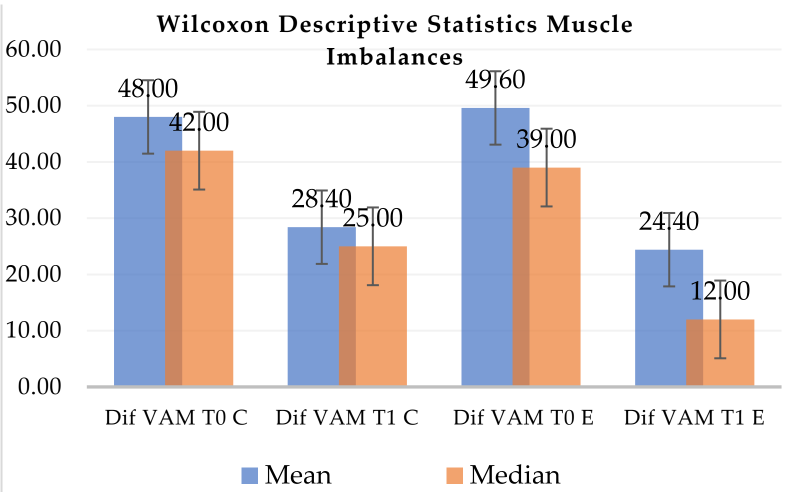


Figure 12. Wilcoxon Descriptive Statistics Muscle Imbalances- VAM

The Wilcoxon test applied to the experimental group after carrying out the standard and proposed physical therapy program, taking into account the assessment of the value to be recovered of muscle imbalances depending, demonstrates statistical relevance (<0.05) p=.043 for both groups. (**Table 12** and **Figure 13**)

Table 12. Wilcoxon Test Statistics Muscle Imbalances

Wilcoxon Test Statistics Muscle Imbalances		
	C (MI T1 - MI T0)	E (MI T1 - MIT0)
Z	-2.023	-2.023
p	0.043	0.043

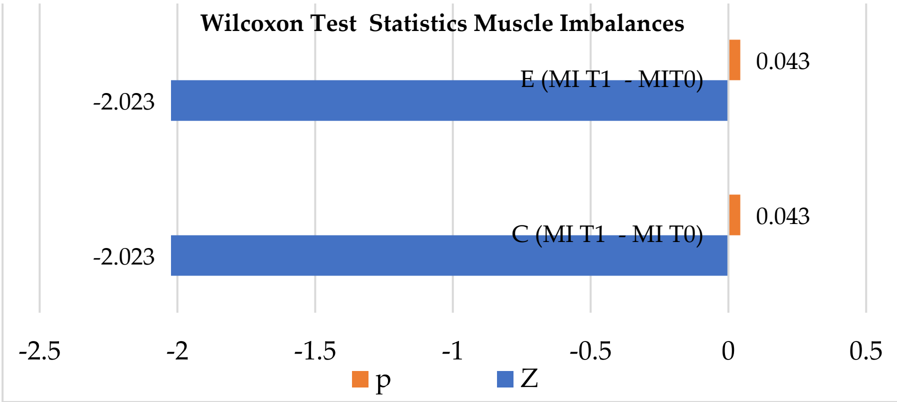
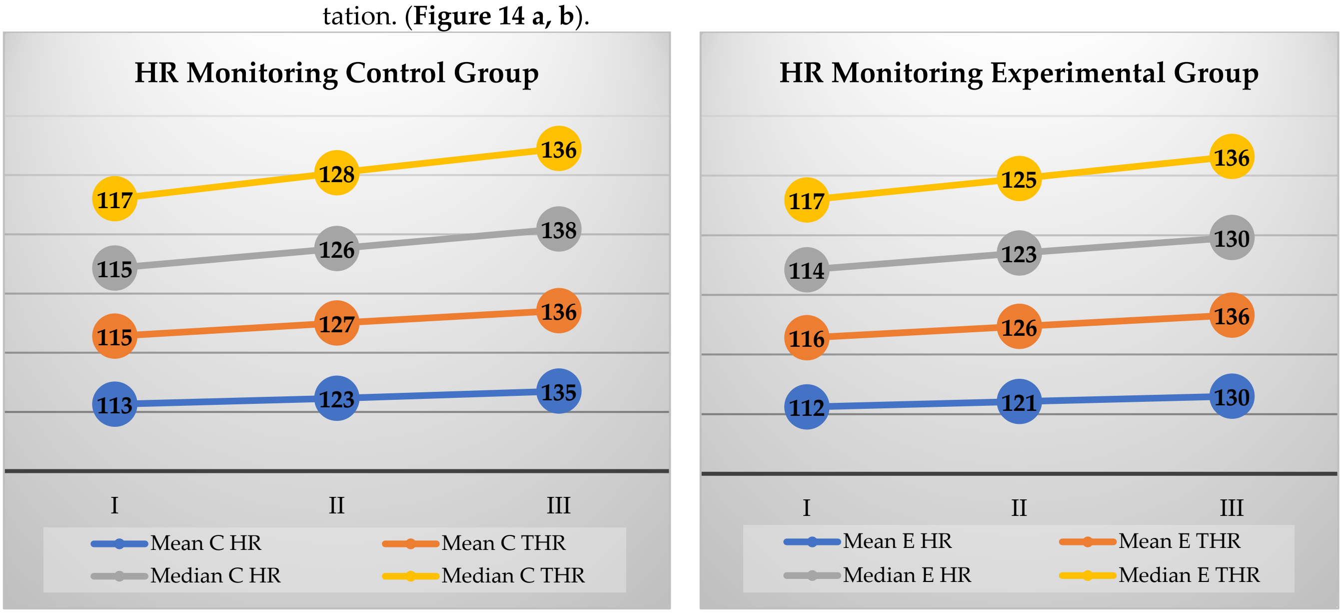


Figure 13. Wilcoxon Test (Z) – p values

2.3.4. Heart rate (HR) reserve

Heart rate reserve or Target heart rate is assessed by applying the Karvonen formula. Target Heart Rate = [(max HR − resting HR) × %Intensity] + resting HR; maximum Maximum HR can be estimated using the formula 215 diminished with age expressed in years multiplied by 0.66. [16,17]. Heart rate monitoring was performed with the Huawei Watch GT 2 Smartwatch, equipped with an optical sensor for heart rate measured during each physical therapy session and before starting rehabilitation for resting heart rate determination. The highest value recorded on the corresponding intensity step was recorded. Mean and median HR values for the control group and experimental group based on three intensity levels changing at every four sessions registered figures below mean and median THR values, aerobic conditioning with the submaximal effort being essential for rehabilitation. (**Figure 14 a, b**).



(**a**) (**b**)

Figure 14. HR Monitoring: (**a**) Control Group; (**b**) Experimental Group

2.3.5 . Borg perceived effort scale

The Borg effort scale was applied to maintain adherence to the treatment and not exceed the lactate threshold during the application of the physical therapy sessions,

The perceived effort was evaluated with the Borg scale, especially since the patients had at least one documented COVID-19 episode in their antecedents following the regulations legislated by the Ministry of Health by Ord.534/2021 [18]. The recorded value was 3 or 4 according to **Figure 15**, which corresponds to a moderate, not very intense effort, respectively mild to moderate dyspnea.

Both programs maintained the same perceived level of effort on a scale from 0 to 10, with an average of 3.6 Borg – moderate, not very intense according to **Figure 15.**

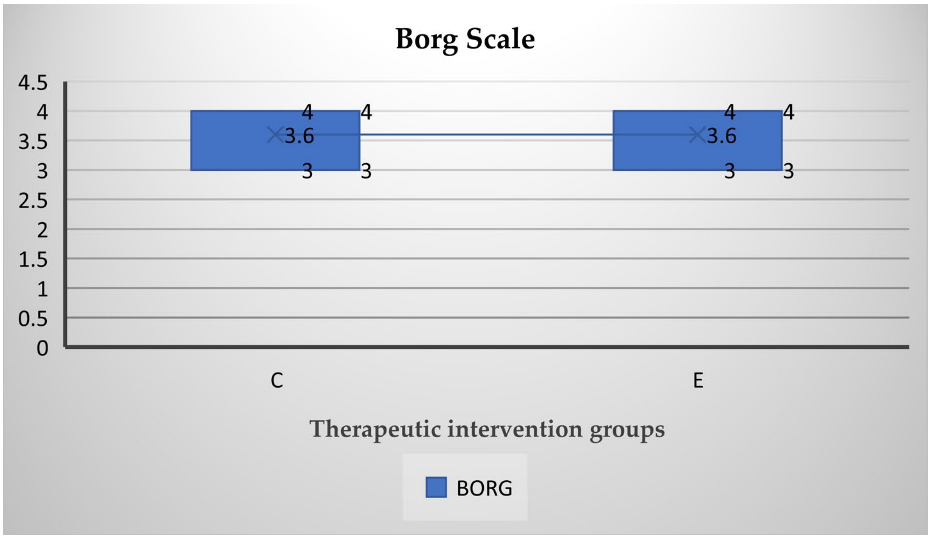


Figure 15. Borg perceived effort scale

4. Discussion

Benefits of stationary cycling include maintenance of joint flexibility, tissue extensibility, abilities for daily tasks, and functional mobility. Additional benefits include improved circulation and tissue nutrition of the limbs and inhibition of pain. Different types of horizontal and vertical stationary bicycles have been tested and included in protocols for different conditions and augmented reality systems are a challenge.

The advantages of using a supine pedaling system (in-bed cycling sessions) are multiple. It involves the safety of using the device even in the critically ill, the normalization of cardiac parameters, the maintenance of the viability of myo-arthro-kinetic structures, and the shortening of rehabilitation time. Also increase the motivation for independent mobilization, the improvement of cognitive functions and survival rates, the prevention and reduction of physical weakness, prevention that can persist for up to a year, the prevention and reduction the physical deficit that can persist even up to 5 years in the case of chronic diseases [19–23].

The activities of the erector lumbar spinal muscles at the level of L3-4, *rectus abdominis*, *gluteus maximus, gluteus medius*, and *biceps femoris* were similar on the horizontal and vertical bikes and varied from low to moderate force levels of muscle activation, essential information for developing strengthening exercise protocols [24]. Ankle joint laxity and lower limb asymmetries in strength and coordination are common symptoms for people with selected musculoskeletal and neurological impairments. The virtual reality augmented cycling kit can serve as a rehabilitation device to monitor biomechanical and physiological variables during cycling on a stationary bicycle [25]. There are projects dedicated to the development of a rhythmic rehabilitation device for physical and neurological rehabilitation, with the use of a stationary bicycle and a virtual reality setup augmented with soundscape sounds to create a higher level of immersion [26]. Another mechatronic rehabilitation system with an interactive virtual environment was designed to benefit users with pedaling asymmetry, using quantitative measures to dynamically direct their attention. It can be used by post-stroke patients with motor deficits [27]. A regimen of structured aerobic exercise performed weekly reported lower levels of depression and improved sleep, participation in community life, and an improvement in overall quality of life among participants after traumatic brain injury [28].

Therapeutic exercise prescription indicates stationary bikes for mobility focus on patients with knee osteoarthritis or meniscus damage. The de-loaded position is useful for reducing effusion, and pain, increasing range of motion, warm-up, generalized endurance, and improving circulation. Pedaling active and active-assisted exercises are suitable for an early home program to improve extension, and starting position knee flexion from 10 degrees [29].

Cycling rehabilitation programs improve balance in patients with deficits in motor function unable to respond effectively to external perturbations. For pulmonary rehabilitation lower extremity activities, including cycling as sustained aerobic exercise, are used to improve exercise tolerance, using large muscle groups. For a patient with amyotrophic lateral sclerosis, the balance between fatigue and tissue atrophy can be reached using submaximal levels. For patients with rheumatoid arthritis or osteoarthritis deconditioned, for whom weight-bearing is a barrier to exercise, low- or non-weight-bearing activities such as stationary cycling, can be a choice [30].

Other pathologies in which pedaling is indicated are chronic fatigue syndrome at the patient's deconditioned state and poor exercise tolerances, lumbar spondylolisthesis, spinal stenosis, scoliosis, hamstring strain, anterior and posterior cruciate ligament repair, total knee arthroplasty [2]. Cycling decreases the effects of stiffness and maintains available motion after resection or repair of an acetabular labral tear osteoplasty, improves cardiopulmonary endurance, increases strength and endurance of knee and hip musculature, improves neuromuscular control/responses, proprioception, stability, and balance, maintain and increase muscle [3].

The perspective followed through this personal study is to include more horizontal pedaling as a part of the rehabilitation programs.

5. Conclusions

Conclusions concern pain, range of motion, and muscle imbalances statistics relevance.

Regarding pain assessment, the conclusion of the **z-test** – C z(t) =10.983, E z(t) =10.590, applied to both groups shows that the mean of the research sample C (5.6±1.140) and E(5.4±1.140) differs significantly from the mean of the standard population (p=.000, CI =95%) before starting the therapeutic rehabilitation programs.

The T-test for paired samples allows the evaluation of the significance of the variation of the VAS "before" and "after" the rehabilitation program. With a significance threshold (p) C/E of.004/.001, an important effect of the recovery programs on both groups can be accepted. Comparatively, the threshold of p=.001 for the experimental group has a higher relevance than the threshold of p=.004 for the control group.

The Wilcoxon test is used to test the difference between values, using the sign of the difference, when both values are measured for the same subjects. At T1, pain perception registered a decrease after applying the standard and proposed physical therapy programs. The control group vs. the related experimental group shows p<0.05, with greater significance for the experimental group p=.039 vs. p=.041 relative to the control group.

Regarding the range of motion, joint balance implied the evaluation by goniometry before (T0) and after (T1) of the performance of the physiotherapy programs.

Wilcoxon test for two paired samples for joint balance showed that both physical therapy programs applied to groups (C/E) of independent patients reveal statistical significance (p<.05) C p=.042, E p=.043.

The t-test of the difference of the means of two dependent samples allows the evaluation of the significance of the variation of the movement amplitude, in the same subjects, in two different situations "before" and "after" the application of the rehabilitation program. There is an effect of the proposed rehabilitation program on the improvement of the joint balance values similar for both groups (p<.05) C p=.000, E p=.001

Regarding muscle imbalances, average analog values were calculated as differences between the lower limbs.

Applying **Paired Differences T-Test** results there is an effect of the proposed rehabilitation program on improving the values of muscular imbalances related to the lower limbs is better than standard. E p =.000; C p =.003, correlation index being .990 for the control group and .997 for the experimental group.

The Wilcoxon test applied to the experimental group after carrying out the standard and proposed physical therapy program, taking into account the assessment of the value to be recovered of muscle imbalances depending, demonstrates statistical relevance (<0.05) p=.043 for both groups.

Regarding monitoring variables. Mean and median HR values for the control group and experimental group based on three intensity levels changing at every four sessions registered figures below mean and median THR values, aerobic conditioning with the submaximal effort being essential for rehabilitation. Both programs maintained the same perceived level of effort on a scale from 0 to 10, with an average of 3.6 Borg, which corresponds to a moderate, not very intense effort, respectively mild to moderate dyspnea.

The conclusion is that the rehabilitation program that included the stationary horizontal bicycle obtained better results in terms of pain control and the correction of muscular imbalances related to the lower limbs, with the mention that both programs recorded statistically significant results regarding functionality. (**Table 13**)

Table 13. Summary Conclusions

Summary Conclusions	VAS		Joint Testing		Muscle Imbalance	
C n=5, 3M, 2W, mean age 58.67 ± 11.67, BMI (kg/m²) mean of 28.17±4.50 2 subjects -40% 40-49 y, one subject - 20% 50-69 y, two subjects – 40% over 70y						
E n=5, 2M, 3W, mean age 56.67 ± 12.14, BMI (kg/m²) mean 27.32±2.94 2 subjects -40% 40-49 y, one subject - 20% 50-69 y, two subjects – 40% over 70y						
Monitoring variables: perceived effort 3.6 Borg, HR < THR (C/E)						
statistical tests p<.05 CI 95%	**C**	**E**	**C**	**E**	**C**	**E**
The T-test for paired samples (p)	.004	**.001**	.042	.043	.003	**.000**
The Wilcoxon test (p)	.041	**.039**	.000	.001	.043	.043
Correlation Index (r)					0.990	**0.997**

SWOT Analyses regarding rehabilitation program using the stationary pedal board enhances the positive items as strengths and opportunities and negative ones. Exercise programs must be cost-effective, logical, and efficient to achieve improvements in motor function promptly. Facilitation of gait is a core objective of rehabilitation that impact the quality of individual life, health system, and society (**Table 14**).

Table 14. SWOT Analyses regarding rehabilitation program using the stationary pedal board

Positive	
Strengths (+) - promising statistic comparative results in terms of reducing pain, re-educating muscle imbalances, and increasing joint range of motion;	**Opportunities (+)** - the emerging need for outpatient rehabilitation; - pedaling systems enhanced with virtual reality are a challenge;

- promoting active movement along the entire kinetic chain of the lower limb; - addressability for deconditioning patients/outpatients; - rhythmic movement, reducing the biomechanical deficit; - good tolerance to effort tested at post-Covid-19 patients too; - interactive interface for observing the pedaling mode thanks to the sensors attached to the pedals connected to the laptop, which leads to the awareness of deficiencies and correction in real time	- the recovery of ambulation related to geriatric patients reduces considerable the expenses of the health system
Negative	
Weaknesses (-) - requires specialized assistance for monitoring perceived effort and heart rate; - patients must be compliant with the recommended personal medication and diet; - resource limitations regarding equipment used and personnel; - number limited of total patients in the study (n=10, C n =5, E n =5).	**Threats (-)** - the underserved market for interactive exercise equipment for lower limbs settled by health insurance; -few specialists accredited in the field of physiotherapy at home.
Internal Factors	**External factors**

Funding:: This research received no external funding

Institutional Review Board Statement: The study was conducted following the Declaration of Helsinki, approval decision no.32/20.10.2021 of the own individual practice cabinet authorized by Public Health of Galati County under no. 096732 / 149 of 11.03.2016.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.
Data Availability Statement: Not applicable

Conflicts of Interest: The author declares no conflict of interest.

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