Original Paper

Assessment and Rehabilitation in Sarcopenic Patients

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ABSTRACT: Sarcopenia is a degenerative disorder that particularly affects older people and is defined by a pathological decrease in muscle strength. This disease represents one of the topics of great interest in the medical world of the last two decades. In our study, we tried to underline the importance of an adapted recovery program based on physical exercise for regaining clinical and functional status in patients with age-related sarcopenia. No nutritional intervention was applied. We performed our rehabilitation program in accordance with present international recommendations for sarcopenia. After complete assessment, our patients were randomised into two groups: G1 (Lot 1=25 patients) and G2 (Lot 2=15 patients). G1 patients were compliant with kinetic training, and performed all rehabilitation measures, and G2 patients accepted rehabilitation program without kinetic exercises. Patients assessment (lab tests, gait analysis, VAS and the Clinical Frailty Scale) was made on two levels-first (T1-inpatient assessment), and after 6 months (T2-outpatient assessment). The rehabilitation program based on the kinetic program brought positive improvements in physical performance and locomotion (gait speed and walking cadence) in sarcopenic patients.

KEYWORDS: *Sarcopenia, gait analysis, rehabilitation.*

Introduction

Sarcopenia, a degenerative ailment defined by a pathological diminution in muscle strength, predominantly impacting the elderly population, has emerged as a subject of significant interest within the medical domain over the past two decades. The European definition of this condition encompasses age-related, involuntary biological aspects (generalized and progressive reduction of skeletal muscle mass), clinical manifestations (reduction in muscle strength), and functional repercussions (physical disability and diminished quality of life), yet without achieving unanimous consensus [1].

The three delineating dimensions are universally acknowledged, demonstrating a logical sequence of interdependence. Notably, the specialized literature emphasizes the need to differentiate sarcopenia from dynapenia, denoting a decline in muscle function or, more precisely, a reduction in muscle strength [2].

Additionally, investigations into other factors influencing neuromotor control are recommended [3].

Similar to the conceptualization of osteopenia as a predictive marker for bone fractures [4], sarcopenia is conceptualized as a precursor to physical frailty, mobility constraints, and premature mortality in individuals experiencing age-related muscle mass decline, mainly attributed to the loss of type II muscle fibers [5].

Epidemiological data exhibit variability, with sarcopenia demonstrating a value of prevalence between 5% to 13% in persons aged 60 to 70 years and 11% to 50% in those aged over 80 years [4].

Recent estimates from 2023 indicate an overall sarcopenia prevalence in older adults ranging from 10.0% to 82.1% [6].

A systematic review revealed sex-specific and setting-dependent variations in prevalence, with rates of 11.2%, 33.7%, and 23.0% for women, and 12.9%, 26.3%, and 29.7% for men in community, nursing home, and hospital settings, respectively. Conservatively estimated, over 50 million individuals are currently suffering from sarcopenia, a figure predicted to escalate to 200 million within the next 40 years [7].

The World Health Organization anticipates a 38% increase in older individuals by 2025 [8].

In contrast to this prevalence variation, international consensus has been established by forums such as the European Working Group on Sarcopenia in Older People (EWGSOP), the Foundation of the National Institute of Health Sarcopenia Project (FNIH), and the International Working Group on Sarcopenia (IWGS). This consensus emphasizes measurable parameters, specifically muscle function and mass (both

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strength and physical performances) for sarcopenia diagnosis [1,9].

Recognized as a significant clinical concern for older individuals and a public health issue, sarcopenia is acknowledged to impair the functionality of elderly individuals alongside conditions like depression and dementia.

However, the consequence of sarcopenia on individual well-being remains incompletely understood [10,11].

Two years ago, experts within the International Society of Physical and Rehabilitation Medicine (ISarcoPRM) proposed a new algorithm for diagnosis. Utilizing the biopsychosocial model of the World Health Organization's International Classification of Functioning, Disability, and Health, they mechanistically reviewed physical activity and sarcopenia pathophysiology from a biomechanical and biological perspective [12].

Assessing sarcopenic patients is a complex medical activity, considering the dynamic nature of skeletal muscle, comprising approximately 40% of entire weight and responding dynamically to physical activity, load, injury, illness, and aging [13].

The keeping of muscle mass hinges on the delicate balance between protein synthesis and proteolysis. Aging disrupts this balance, leading to the cancellation of muscle mass and muscle function [14].

Various factors contribute to sarcopenia, including genetic predisposition, inactivity, age-related increases in proinflammatory cytokines (such as Interleukin-6, tumor necrosis factor-alpha and C-reactive protein), impaired mitochondrial function, abnormal myokine production, malnutrition, hormonal reductions, metabolic disorders, insulin resistance, lipodystrophy, and an overactive renin-angiotensin system (RAS) [4,13,15,16,17].

Clinical and functional assessment dynamics in sarcopenic patients aim to address which tests should be considered for measuring muscle mass (appendicular skeletal muscle mass) and assessing muscle function and physical performance. Various screening tests and suggested cutoff values are proposed by different working groups [5].

Accurate administration and interpretation of these tests are crucial for optimal rehabilitation programs, enhancing muscle parameters (strength, power, endurance), coordination, physical performance, and overall quality of life.

It is imperative to categorize sarcopenia accurately as primary (age-related) or secondary, where identifiable causes such as decreased activity/inactivity, disease (inflammatory and endocrine diseases, organ failure, malignancies, cancer cachexia), and poor nutrition are implicated [1,18].

In our country, sarcopenia evaluation has been a relatively overlooked topic until the last decade. Despite recent developments in research on sarcopenic patients in Romania, few studies focus on the effects of rehabilitation programs applied to primary sarcopenia patients. This study aims to emphasize the importance of an adapted recovery program based on kinetic measures in regaining clinical and functional status for sarcopenic patients, specifically those with age-related sarcopenia. No nutritional interventions were implemented, aligning with current international management recommendations for sarcopenia [7,19].

Patients and Methods

In 2022, we conducted an open-label, single-arm pilot study in the Rehabilitation Department of the “Filantropia” Hospital Craiova.

The agreement from the Ethics Committee of Craiova University of Medicine and Pharmacy was obtained and all patients. The signed an informed consent number is 204/20.09.2023

65 patients were included. We took into consideration the following criteria:

- age over 65;
- compliance with kinetic program;
- no major co-morbidities, but well controlled dysplipemia, arterial hypertension, and mellitus diabetes type II; mild/moderate osteoarthritis, mild chronic obstructive pulmonary disease, hypothyroidism;
- no injuries in the last 6 months;
- self-reported using a questionnaire;
- value of screening test for sarcopenia greater than 4.

We did not include patients with:

- dependent living condition (including orthopedic surgery);
- incapacity to walk a distance of 200m;
- immobilization for 7 days during the last 2 months;
- presence of severe morbidities (recent malignancy, neurologic and hematologic disorders, psychiatric disorders, severe respiratory disease, heart failure);
- use of immunosuppressive drugs and/or insulin therapy.

All patients completed screening test for sarcopenia-SARC-F (this test includes five

components-Strength, Assistance with walking, Rise from a chair, Stair climbing and history of Falling-with to 2 points for each component; the test score range from 0 to 10; a value equal to or greater than 4 is predictive of sarcopenia) [20].

After preliminary screening, 40 patients were completely assessed, for establish positive diagnose of sarcopenia. We made complete evaluation-etiopathogenic, clinical, lab screening and functional assessment. We performed the standard recommendation for this:

- a whole body scan was determined using dual-energy X-ray absorptiometry (DXA) (DEXA bone densitometer MEDIX 90, version V3.0.8.3, France). Total and compartmental fat mass and lean mass were measured. The lean body mass (LBM) is important for an estimation of muscle mass; the cut-off values-women: <5.5kg/m2, men: <7.26kg/m2 [21];
- anthropometric measurement-body mass (kg), height (m), body mass index (BMI-kg/m2), mid upper arm circumference (MUAC-ccircumference at halfway point between the acromion and olecranon process while arm is bent at 90^0, the cut-off value is <22.5cm) [21];
- handgrip strength (HGS) was determined using the Saehan Squeeze Dynamometer; patients were instructed to stand upright with the dynamometer beside, but not against their body. Maximal isometric effort for 5 seconds were performed for dominant side, three times. The best measure of all was considered for study; the cut-off value women: <16kg and men: <27kg (2,26) [21];
- physical performance was assessed by speed of walking scheme through the Timed Up-and-Go (TUG) test (patients rises from a chair without the use of arms, walks around the cone placed 3 m from the chair, and returns to seated; the time is joined). Further instructions were to complete the test as quickly as possible, while taking care not to run and to remain safe. Participants were allowed three trials; the fastest attempt was used for analyses. The resulting time (s) was transformed into an estimate of walking (gait) speed (GS) by using the formula (6/(TUG time))×1.62. Low gait speed means value ≤0.8m/s [22].

During the assessement, we made a laboratory examination and gait analysis. The laboratory examination included: screening laboratory test, fibrinogen, C reactive protein-CRP, lipid profiles, biochemical biomarkers-adiponectin, leptin, tumor necrosis factor-alfa TNFα, using commercially available kits based on sandwich enzyme linked immunosorbent assay technique, purchased from Biovendor R&D, Brno, Czech Republic.

For walking scheme analysis we used a wireless system-BTS G-WALK (BTS Bioengineering Corp., Italy). This device is an inertial sensor composed by a magnetic sensor, a tri-axial accelerometer, and a tri-axial gyroscope. It is worn by the patient and permitted a real functional gait analysis. The gait parameters allowed to measure the functional capacity of sarcopenic patients before and after rehabilitation program. These parameters were:

- Symmetry index-the patient's ability to have an identical model of acceleration and deceleration of their center of mass regardless of the side of the gait cycle;
- Six Minutes Walking Test (6 MWT= 6 MWD)- "walking distance" (m) and „average cadence" (steps/min).

In order to assess the functioning of our patients we used:

- the Visual Analogue Scale (VAS)-where 10 means maximal pain and 0 represents the patient has no pain; values are directly proportional to the intensity of pain;
- the Clinical Frailty Scale (CFS)-an accessible instrument that can be used to quickly assess sarcopenia (a major compeonet of frailty) and frailty, for adults aged over 65 years. The Clinical Frailty Scale focuses on items that can be readily observed including balance, mobility, use of walking aids, and the abilities to dress, eat, shop, cook, and bank. The descriptions and pictographs of activity and functional status suggest the scores from 1 (very fit) to 9 (terminally ill). Higher scores indicate associated risks and increased frailty/sarcopenia [23].

After complete assessment, our patients were randomised into two groups: G1 (25 patients) and G2 (15 patients). G1 patients were compliant with kinetic training, and performed all rehabilitation measures, and G2 patients accepted rehabilitation program without kinetic exercises (diagram of our study).

Before establishing the rehabilitation program, our *healthcare objectives* were:

- pain and weakness management;
- muscle strength and motor control recovery;
- correction of the abnormal system of walking;
- preserving and enhancing the quality of life.

The rehabilitation program included the following measures:

- education, diet and hygiene;

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- electrotherapy-12 sessions of magnetic therapy, TENS, electrical stimulation and mechano-sound vibration (deep oscilation) for quadriceps, biceps brachii anf flexor muscles of hand;
- sedative massage;
- kinetotherapy;
- pharmacological measures-daily medication for co-morbidities.

Kinetic exercises were personalized, depending on patient resources and on pain and weakness status. After in-patients program (12 sesssions), we recommended daily home-training for studied patients. We respected the three principles of training exercise: specificity, overload and progression [24].

In each in-patients kinetic session, a daily 40-minute exercise program was executed. Before and after each session, 10-minute period of warm up and cool-down was included. We recommended cycle-ergometer (15 minutes) and stretching daily, whole-body resistance training (targeting the major muscle goups) every 3 days for week, balance and gait training 3 days for week (various type of walking, rising from a chair, climbing stairs). After 3-4 weeks of kinetic program, we included strengthening exercises for back extensor, quadriceps and flexor muscles of upper limb; exercise intensity was individually defined, based on the maintenance time of each exercise and number of repetitions, and did not exceed 80% of the maximal amount of weight that can be lifted for one complete repetition.

Each patient had received an exercise booklet for home-training. We encouraged all patients to performe the resistance traning 2-3 days for week and walking 5000-6000 steps daily.

Patients assessment (lab tests, gait analysis, VAS and the Clinical Frailty Scale) was performed on two levels-first (T1-inpatient assessment), and after 6 months (T2) in the outpatient assessment. Durind these months, patients performed the kinetic program trained in the hospital.

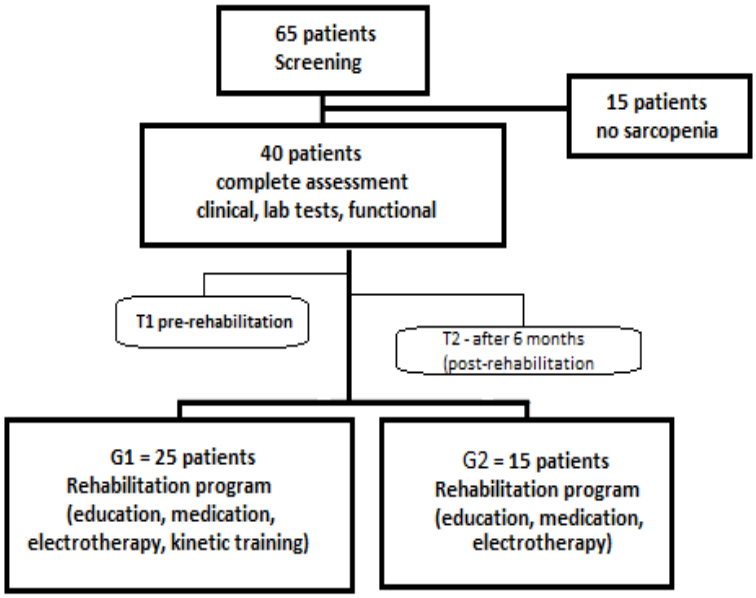

Figure 1. Diagram of our study.

Statistical analysis

Data were recorded in Excel files (Microsoft, USA), and subsequent descriptive and inferential statistical analyses were conducted, involving both Excel and MATLAB (Mathworks, USA). Scale values were perceived as numeric. Normality assessment of data was made using the Kolmogorov-Smirnov and Shapiro-Wilk tests.

Parametric tests (Student t-test and ANOVA) were applied to assess mean differences among groups when normal distribution was observed in all groups, while non-parametric tests (Mann-Whitney, Kruskal-Wallis) were utilized if at least one group did not have a normal distribution. Significance was determined at a p value <0.05. Variables are presented as mean±standard deviation (SD), and box plots were employed for data visualization.

Results

Our study comprised 40 patients diagnosed with sarcopenia, as per the guidelines outlined by the European Working Group on Sarcopenia in Older People 2 (EWGSOP2). The gender distribution within both groups exhibited a noteworthy skew, with over 85% of patients being women, a statistically significant deviation from the general population's sex distribution (z score for proportions <0.001). A distinct rural/urban ratio was observed, with G1 showing a ratio of 18:7 (2.57) and G2 exhibiting a ratio of 13:2 (6.5), indicating a possible conditioning of the area of residence on the studied condition.

In both groups, the mean value for age was nearly identical, with G1 averaging 74.5 years and G2 73.5 years, reflecting a minimal one-year difference between mean values (see Table 1). The Body Mass Index (BMI) were situated towards higher values, indicating an association between sarcopenia and overweight status, particularly pronounced in G1. Notably, BMI exhibited a significant correlation with gender, revealing that females had a higher BMI compared to males.

Table 1. Demographic data of studied patients.

Demographic parameters		Group 1 (G1=Lot 1=25 patients)			Group 2 (G2=Lot 2=15 patients)		
		Min	Max	Mean (SD)	Min	Max	Mean (SD)
Age		64	88	74.5 (5.9)	62	84	73.5 (5.4)
Weight (Kg)		50	102	72.3 (14.7)	40	109	63.7 (18.6)
Height (m)		1.46	1.7	1.6 (0.1)	1.5	1.72	1.6 (0.1)
BMI (Kg/m^2)		19.47	45.51	28.6 (6)	17.01	36.84	25.4 (5.8)
Sex	Female	23 females (92%)			13 females (86.66%)		
	Male	2 male (8%)			2 male (13.33%)		
Residence	Urban	7 patients			2 patients		
	Rural	18 patients			13 patients		

We instituted a rehabilitation program as the primary therapeutic intervention for our cohort of sarcopenic patients. In Group 1, we supplemented pain and functional assessments with kinetic measures. In our investigation, participants in both treatment groups exhibited notable enhancements across all evaluated parameters at T2 in comparison to their baseline status at T1 (refer to Table 2, Table 3, and Table 4).

Clinical assessment

We used six clinical parameters in our study (Table 2):

- mid upper arm circumference (MUAC),
- handgrip strength (HGS),
- Timed Up-and-Go (TUG) test,
- Symmetry index,
- Six Minutes Walking Test (6 MWT= 6 MWD),
- Walk cadence or average cadence (steps/min).

At the T1 time point, there existed no statistically significant differences between the values obtained from the two groups in the examined parameters. However, at the T2 time point, subsequent to six months of engaging in the kinetic program within the G1 group, statistically significant differences were exclusively noted for the 6-Minute Walk Test (6MWT). Specifically, the values for G1 demonstrated a noteworthy increase compared to those for G2 (p for t-test=0.0007<0.001-indicating a highly significant difference).

Comparing the initial mean values with the final ones, as seen in Figure 2, we obtained the following statically significant results (Student t test) results:

- Six Minutes Walking Test-for both groups;
- Average cadence or Walk cadence (steps/min)-for both groups;
- Symmetry index-for both groups;
- Timed Up-and-Go test-only for G1 group.

We noticed no significant difference for the handgrip strength (HGS) and mid upper arm circumference (MUAC) in all patients; although the difference was greater for G1, it did not reach the limit of statistical significance.

Table 2. Clinical parameters values in all studied patients.

G1 (25 patients) G2 (15 patients)	6 MWT (6 MWD)				Walk cadence (Cad)			
	INITIAL (T1)		FINAL (T2)		INITIAL (T1)		FINAL (T2)	
	G1	G2	G1	G2	G1	G2	G1	G2
Minimum	215	230	220	270	84.4	87.1	65.8	73.3
Quartile 1	280	240	345	362.5	95.4	95.8	83.6	87.6
Median	330	270	415	400	108	102.6	92.7	93.6

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Quartile 3	360	310	450	440	110.6	112.3	101.4	106.6
Maximum	430	345	520	475	116.9	117.1	113	109.8
G1 vs G2 (p / T test)	NS	0.696	**HS**	**0.007**	NS	0.931	NS	0.178
Final vs Initial G1 (p / T test)	**HS=0.000**				**HS=0.000**			
Final vs Initial G2 (p / T test)	**HS=0.000**				**S=0.035**			
Mean	320.3	277.7	403.4	395.7	103.6	103.3	89.1	94.9
Standard deviation	55.8	38.7	67.2	55.4	9.6	9.5	15	11.3
G1 (25 patients) G2 (15 patients)	**TUG**				**Symmetry Index (Sym)**			
	INITIAL (T1)		**FINAL (T2)**		**INITIAL (T1)**		**FINAL (T2)**	
	G1	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**
Minimum	17.89	19.67	17.43	17.01	79.4	87.9	93.5	95.9
Quartile 1	20.33	21.96	19.74	19.17	87.2	91.9	94.2	97.15
Median	23.46	24.58	22.06	21.03	91	93.9	95.8	97.5
Quartile 3	25.02	25.55	23.48	23.44	95.5	95.65	97.5	98
Maximum	27.28	27.65	29.05	25.06	98.7	97.2	98.7	98.8
G1 vs G2 (p / T test)	NS	0.526	NS	0.195	NS	0.163	NS	0.089
Final vs Initial G1 (p / T test)	**HS=0.008**				**S=0.025**			
Final vs Initial G2 (p / T test)	NS=0.219				**S=0.014**			
Mean	25.0	23.6	22.6	21.2	90.5	92.9	94.3	96.6
Standard deviation	8.7	2.5	4.4	2.6	6.4	4.3	5.1	3.1
G1 (25 patients) G2 (15 patients)	**MUAC**				**HGS**			
	INITIAL (T1)		**FINAL (T2)**		**INITIAL (T1)**		**FINAL (T2)**	
	G1	**G2**	**G1**	**G2**	**G1**	**G2**	**G1**	**G2**
Minimum	17.5	17.4	17	18	7	8	7	9
Quartile 1	18.5	17.9	19	18.5	9	9	9	10
Median	19.6	19	19.6	19.6	10	10	11	11
Quartile 3	21.5	19.8	21	20.5	11	12	12	13
Maximum	22.6	22.3	22.4	23	13	16	14	17
G1 vs G2 (p / T test)	NS	0.282	NS	0.944	NS	0.555	NS	0.267
Final vs Initial G1 (p / T test)	NS=0.971				NS=0.449			
Final vs Initial G2 (p / T test)	NS=0.372				NS=0.301			
Mean	19.9	19.3	19.9	19.9	10.3	10.8	10.8	11.8
Standard deviation	1.6	1.3	1.5	1.8	2.2	2.6	2.6	2.6

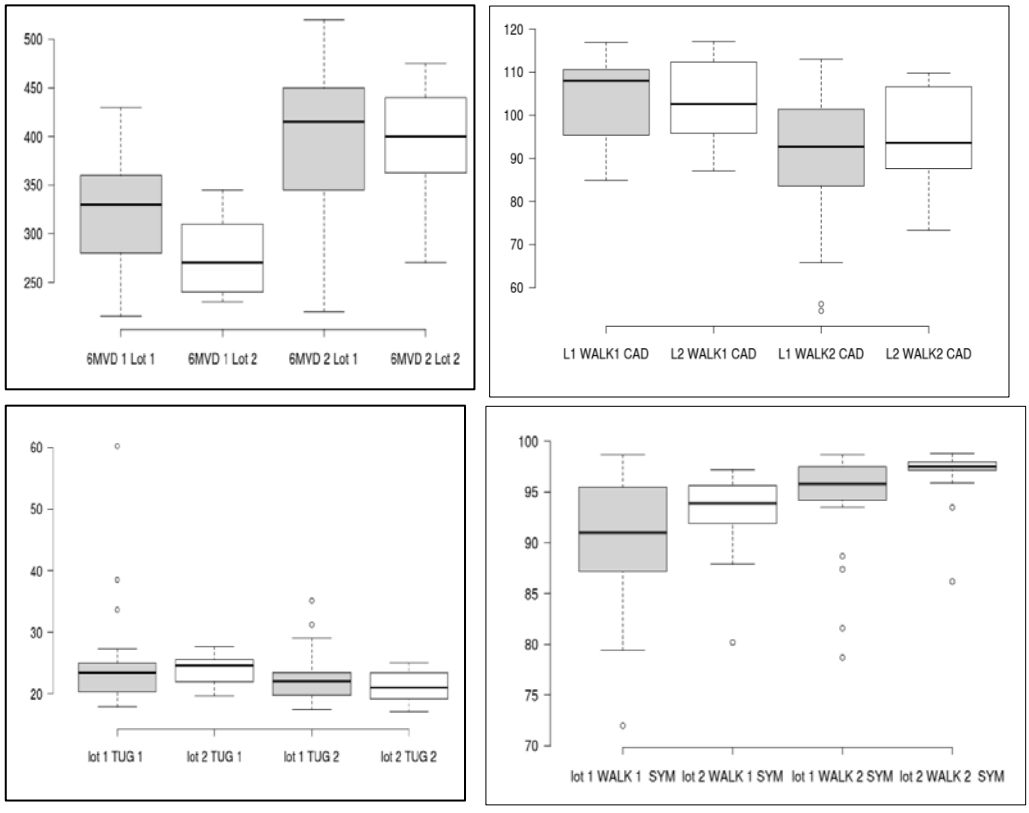

Figure 2. Clinical parameters values.

The estimation of gait speed (GS) in our patient cohort was derived using the formula (6/TUG time)×1.62. In Group 1 (G1), the mean GS at T1 was 0.38m/s, increasing to 0.43m/s at T2. For Group 2 (G2) patients, the mean GS at T1 was 0.41m/s, progressing to 0.45m/s at T2.

Notably, all patients exhibited values ≤0.8m/s, indicative of a low walking speed.

Following six months of engagement in the kinetic program, G1 patients demonstrated a 13% improvement in gait speed, surpassing the 9% improvement observed in G2 patients.

The lab data (Table 3) was followed as other studied parameters. The mean values for all biochemical and inflammatory tests were within their physiological interval.

So, we could apply rehabilitation program in safe conditions. We obtained significant differences between the groups and evaluation moments only for alkaline phosphatase and biochemical biomarkers-adiponectin, leptin, tumor necrosis factor-alfa (TNFα).

Table 3. Lab data of studied patients, with significant differences.

Lab parameters		Group 1 (G1=25 patients)			P (T test)	Group 2 (G2=15 patients)			P (T test)
		Min	Max	Mean (SD)		Min	Max	Mean (SD)	
Fibrinogen	T1	160	494	330.9 (80.1)		176	663	366.3 (117.7)	
	T2	233.8	703	381.8 (111.2)		258	595	370.7 (80.2)	
C Reactive Protein	T1	0.04	2.51	0.5 (0.6)		0.04	5.4	1.1 (1.5)	
	T2	0.04	5.3	0.8 (1.3)		0.02	2.98	0.6 (0.7)	
Cholesterol	T1	128	301	209.2 (48.4)*	*p=0.043	69	286	195.1 (62.1)	
	T2	125	250	175.3 (36.2)*		137	280	203.9 (43.7)	
Triglycerides	T1	39	309	115.8 (59.1)		53	218	107.1 (43.5)	
	T2	64	202	112.3 (39.9)		62	224	126.3 (56.6)	
Alklaline Phosphatase	T1	39	182	73.2 (30.8)*	*p=0.004	41	95	63.6 (15.7)	
	T2	32	115	68.7 (15.8)*#	# p=0.000	45	100	70.1 (16.5)#	# p=0.000
Adiponectin	T1	14.96	30.70	26.3 (5.1)*	*p=0.004	15.49	30.76	23.6 (4.8)	
	T2	25.6	39.9	33.8 (4.8) *#	# p=0.000	16	32.6	25.2 (4.9) #	# p=0.000
Leptin	T1	14.06	73.89	51.4 (13.6)*	*p=0.001	27.18	69.43	47.2 (13.9)	
	T2	14.26	70.57	39.4 (19.4) *#	# p=0.004	26.94	61.5	34.5 (17.8)#	# p=0.004
TNFα	T1	26	32	29.9 (2.0) *	*p=0.000	23	36	29.2 (2.6)	
	T2	19.5	30	26.2 (3.4) *#	# p=0.005	18	32.5	26.1 (3.1)#	# p=0.005
* p value between T1 and T2 parameter values, for both groups # p value between G1 and G2 parameter values in T2 assessment									

Functional evaluation was made with two scales (Table 4): the VAS-Visual Analogue Scale and the Clinical Frailty Scale (CFS or SFC). A moderate impairment was obtained in all patients; the mean value of Clinical Frailty was nearly 5; after 6 months of treatment, the value of CFS was nearly 4.

Table 4. Functional parameters values in all patients.

G1=Lot 1 (25 patients) G2=Lot 2 (15 patients)	VAS scale				Clinical Frailty Scale (CFS or SFC)			
	INITIAL (T1)		FINAL (T2)		INITIAL (T1)		FINAL (T2)	
	G1	G2	G1	G2	G1	G2	G1	G2
Minimum	2	4	3	2	4	4	3	3
Quartile 1	5	4.5	4	3	5	4	3	3
Median	6	6	4	4	5	5	4	4
Quartile 3	7	6.5	5	5	6	5	4	4
Maximum	8	8	6	7	6	6	5	4
G1 vs G2 (p / T test)	NS	0.529	NS	0.880	NS	0.963	NS	0.205
Final vs Initial G1 (p / T test)	**HS=0.0000**				**HS=0.003**			
Final vs Initial G2 (p / T test)	NS=0.523				NS=0.195			
Mean	5.9	5.6	4.1	4.2	5.1	4.7	3.7	3.7
Standard deviation	1.4	1.3	1.2	1.8	0.7	0.7	0.7	1.0

We analyzed the differences between the values obtained between the two groups of patients (Figure 3).

We found that there was no statistically significant difference for any of the two parameters, for the both moments T1 and T2.

Comparing the initial values with the final ones, we obtained the following results:

VAS scale-a highly significant difference (p T test <0.001) for patients in the G1 group followed six months of kinetic program;

Clinical Frailty Scale (CFS or SFC)-a significant difference (p T test <0.05) for patients in the G1 group followed six months of kinetic program.

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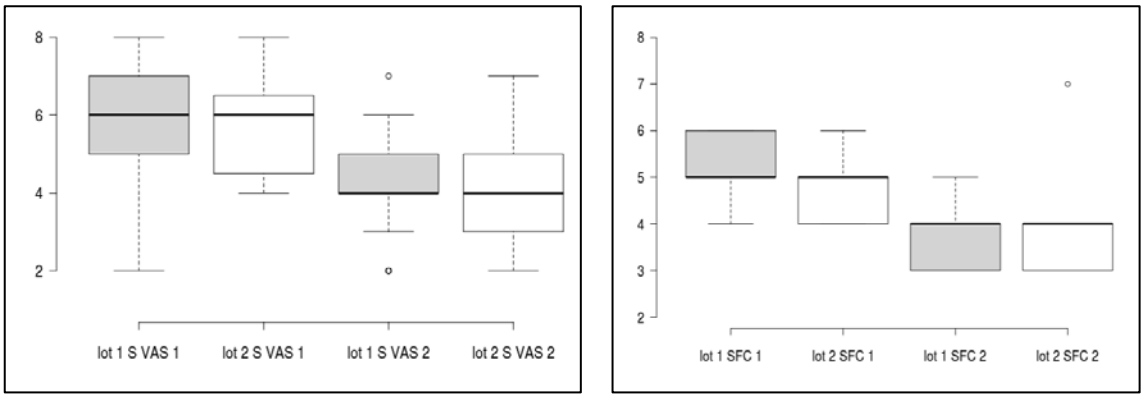

Figure 3. Functional parameters values.

Discussions

There are extremely few national studies that have examined the rehabilitation effects in sarcopenic patients. Our original study aimed, firstly, to enhance understanding and knowledge of sarcopenia in elderly individuals and, secondly, to assess the beneficial effects of a rehabilitation program tailored for these patients.

The majority of the participants were female, constituting 92% (23 patients) in G1 and 86.66% (13 patients) in G2, aligning with findings from previous investigations. This gender discrepancy may be attributed to hormonal factors and reduced muscle mass [25].

Furthermore, cumulative disadvantages experienced by women throughout their lives, such as limited access to education and food, increased susceptibility to poverty, and a higher likelihood of health problems, may contribute to the observed prevalence in females, particularly in old age [6].

We adhered to the screening stages recommended by the 2nd European Working Group on Sarcopenia in Older People (EWGSOP2). According to EWGSOP2, sarcopenia is characterized as a "progressive and generalized skeletal muscle disorder associated with an increased likelihood of adverse outcomes, including falls, fractures, physical disability, and mortality" [26].

To determine lean body mass in our patients, we conducted a dual-energy X-ray absorptiometry (DXA) scan for total body (see Figure 4).

This examination facilitated the quantification of appendicular lean mass reduction, assessment of fat tissue quantity and distribution, and exploration of inter-limb lean mass asymmetry [27].

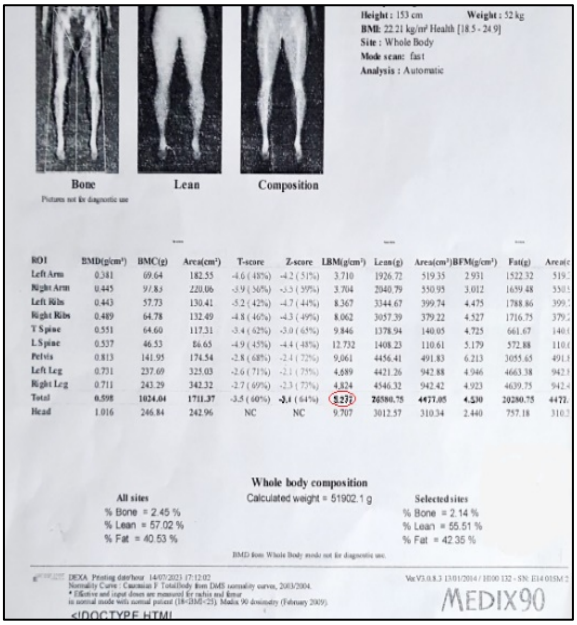

Figure 4. A total body dual-energy X-ray absorptiometry.

We refrained from utilizing appendicular lean mass (ALM) parameters, which encompass the sum of arms and legs, as these are deemed more pertinent to activities of daily living and are recommended in the delineations of sarcopenia [28].

Currently, there is an absence of consensus regarding a definitive "dual-energy X-ray absorptiometry (DXA) index for muscle mass determination" in the diagnosis of sarcopenia [29].

Ideally, measurements of muscle mass via DXA should be complemented with tests for muscle function and physical performance metrics. These tests have to analyze in conjunction with clinical data, as the assessment of muscle mass alone may not adequately ascertain a subject's risk for sarcopenia.

Consequently, we conducted an extensive evaluation of our sarcopenic patients, encompassing clinical, paraclinical, and

functional assessments. The examined parameters were established at both T1 and T2 time points to monitor the impact of rehabilitation.

In our trial, we observed improvements in all parameters, with a notably higher percentage of improvement observed in Group 1 (G1) patients, who participated in the kinetic program.

Specifically, Handgrip Strength (HSG) increased by 14% in G1 compared to 3% in Group 2 (G2), the 6-Minute Walk Test (6MWT) significantly increased by 33% in G1 compared to 26% in G2, Walk Cadence improved by 12% in G1 compared to 8% in G2, and gait speed increased by 14% in G1 compared to 12% in G2. These results are attributed to the implemented differentiated program.

Muscle Upper Arm Circumference (MUAC) and the symmetry index in gait analysis exhibited minimal improvement for both groups. Notably, the kinetic program excluded coordination exercises and specific upper limb strength exercises.

The rehabilitation program resulted in an enhancement of functional status, as evidenced by a 30% increase in the Visual Analog Scale (VAS) in G1 compared to 25% in G2 and a 27% increase in the Clinical Frailty Scale (CFS) in G1 compared to 21% in G2.

While the VAS scale is not a routine tool in sarcopenia research, we adopted it, as suggested by Karttunen et al., recognizing that muscle strength, influenced by multiple factors (pain status, joint and cardiovascular functions, neural control), can impact screening and pain assessment [30,31].

Mild to moderate scores of CFS in our study indicate mild to moderate sarcopenia, and the change in the score serves as relevant evidence for the effectiveness of the applied kinetic program. Our results suggest that CFS could be a useful instrument for evaluation of functional status and quality of life in sarcopenic patients before and after rehabilitation.

In conjunction with the CFS value, Handgrip Strength (HGS) and Timed Up and Go (TUG) test scores corroborated the severity of sarcopenia, aligning with existing literature [32,33].

Muscle strength, particularly HGS, walking speed, and TUG test, exhibited similar patterns in elderly participants, with HGS increasing with age, stabilizing, and eventually declining [34].

Bijlsma et al. proposed that muscle strength in the old people correlates with both muscle mass and physical status. The decline of muscle mass is strongly linked to the loss of muscle strength, albeit not at the similar proportion, possibly due to the lack of adjustment for body or fat masses [35].

HGS measurement, being simple and cost-effective, correlates strongly with muscle strength from various muscle groups and serves as a reliable surrogate for complex measurements [36].

These measures can aid in identifying sarcopenic patients at risk for other impairments and evaluating the efficacy of a comprehensive rehabilitation program [37].

Our assessment of patient gait, encompassing 6MWT, Symmetry Index, and Walk Cadence, aimed to address alterations resulting from reduced muscle mass, leading to changes in gait patterns among sarcopenic elderly individuals. Walking speed, calculated using the formula $(6/(\text{TUG time}))\times 1.62$, was considered a crucial indicator of physical functioning, associated with fall risks, neuromuscular status, and cognitive ability in sarcopenic patients [33].

Both the 2nd Edition of the European Working Group on Sarcopenia Standards (EWGSOP2) and the Asian Working Group for Sarcopenia Standards (AWGS) include the speed in the gait scheme as a diagnostic criterion for sarcopenia. Our study results affirm that kinetic exercises increase the walking speed of the patients, aligning with prior research indicating large effects for studies incorporating elastic resistance exercise, resistance exercise, and walking-based home programs [38,39].

Despite the observed improvements in gait, a significant level of difference exists among studies, attributed to walking speed test variables. A standardized measurement for walking speed is advocated to enhance study comparability and reduce the actual differences [40,41].

Among the study participants, 14 patients (10 in G1 and 4 in G2) were obese, categorizing them as having sarcopenic obesity. Post-rehabilitation, physical performance and gait parameters exhibited improvements, albeit to a lesser extent compared to the average values for each group. This aligns with findings in a study by Zhuang et al. in 2022 [42], suggesting that sarcopenic obesity patients, characterized by lower physical activity, increased caloric intake, and higher risk of dyslipidemia, demonstrate less pronounced improvements following rehabilitation. Moreover, age-related increases in intramuscular and visceral fat, coupled with

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declines in subcutaneous fat, contribute to adipose tissue accumulation around and between muscle fibers, correlating with reductions in muscle cross-sectional area.

Sarcopenia is closely intertwined with disruptions in cellular mechanisms and striated muscle physiology and, manifesting across cellular, vascular, inflammatory, and metabolic compartments [43].

In light of these changes, our study considered hematological parameters, encompassing inflammatory markers, lipid profiles, and biochemical biomarkers such as tumor necrosis factor-alpha (TNF-α) and two adipokines (adiponectin and leptin).

Previous research by Tuttle et al. in 2020 emphasized the frequent use of markers like TNF-α, interleukin-6 (IL-6), and C-reactive protein (CRP) for assessing inflammation in relation to muscle mass and strength, varying by population and gender [13].

Recent insights indicate a connection between chronic inflammation, often referred to as 'inflammation' in the aging process, and muscle mass loss. Aging introduces physiological changes fostering low-grade chronic inflammation, influenced by pro-inflammatory factors, cellular aging processes (senescence), and shifts in lipid metabolism within muscle tissue [44].

Our findings revealed significant improvements in cholesterol levels among G1 patients' post-rehabilitation, coupled with notable changes in biochemical biomarkers (adiponectin, leptin, TNF-α) correlated with immune cell activity and increased production of reactive oxygen species, indicative of cellular damage in sarcopenic patients [45].

CRP and fibrinogen, as easily accessible markers of inflammation, were within normal limits, aligning with the mild severity of sarcopenia observed. We speculate that regular adapted physical training induces a complex and dynamic response in skeletal muscles, impacting biomarkers such as TNF-α, IL-6, CRP [46].

The rehabilitation program involved a comprehensive assessment, and all patients participated in a kinetic program with the goal of maintaining and enhancing muscle strength, mass, and physical function. Commencing with low-load exercises, the program progressively increased intensity. This approach resonates with existing medical literature highlighting the multifaceted role of resistance training, with or without additional physical training, tailored to individual factors like age, gender, comorbidities, and functional status of the sarcopenic patient.

Numerous global studies underscore the crucial importance of kinetic training in preserving and restoring functioning in sarcopenic patients. Recent meta-analyses and randomized controlled trials affirm the effectiveness of resistance exercise, either alone or in combination with other forms of training, in improving quality of life and physical function in sarcopenic individuals [7,41,42].

Resistance exercise, especially when combined with aerobic and balance training, emerges as a potent intervention for enhancing body composition, muscle strength, physical performance, and insulin-like growth factor 1 [42,47].

While the efficacy of exercise interventions is widely recognized, the optimal training strategy requires further exploration, considering multiple variables and outcomes in a larger population. Emerging approaches, such as virtual reality-based rehabilitation, demonstrate effectiveness in older populations, albeit with limited studies focused on sarcopenic patients [50].

When exercise programs are coupled with nutritional therapy, superior outcomes are noted. Early initiation and tailored adjustments based on disease status prove beneficial for muscle mass gain, strength building, and overall functional recovery [18].

The unanimous consensus across various studies supports exercise as a primary intervention for sarcopenia. We advocate the sustained implementation of home kinetic programs to uphold normalcy and preserve functional gains. The focus on lower extremities during exercise interventions aims to stimulate muscle mass effectively.

Our patients underwent a recovery program involving kinetic and physical measures. Electric measures, specifically local electromyostimulation, were applied for pain control and muscle recovery. Unlike whole-body electromyostimulation (WB-EMS), which is commonly employed in sarcopenic obese patients, we opted for a localized approach.

WB-EMS involves simultaneous stimulation of multiple muscle groups and is considered a safe method for augmenting muscle mass and functional capacity.

The patient-centered dimension of our rehabilitation program aligns with the WHO European framework for action, emphasizing the

health and well-being promotion of persons with disabilities.

Acknowledging the growing population of individuals with disabilities, our approach aims to achieve the highest attainable standard of health across all age groups and contexts within the WHO European Region [52].

The limits of our study were:

- small number of patients in the two groups;
- assessment of muscle strength only in upper limb;
- absence of nutritional interventions (protein intake), as it was mentioned in medical literature since 2020 [53].

Conclusions

1. In the assessment of elderly individuals, it is imperative to implement strategies encompassing screening for probable sarcopenia, diagnostic confirmation for confirmed sarcopenia, and the categorization of disease severity.
2. Individuals diagnosed with sarcopenia exhibited favorable enhancements in physical performance and locomotion, specifically gait speed and walking cadence, following participation in a rehabilitation program rooted in kinetic principles.
3. Additionally, the kinetic program demonstrated potential direct benefits by addressing fundamental mechanisms contributing to sarcopenia, including the reduction of inflammation and diminished fat infiltration.
4. The comprehensive evaluation and physical training of older patients within an interdisciplinary framework contribute to enhanced functionality in daily life, thereby exerting control over physical disability.

Conflict of interests

None to declare

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