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EFFECTS OF KINESIOTHERAPY VERSUS HIDROKINETIC THERAPY ON THE REHABILITATION OF PATIENTS WITH AMPUTATION

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Abstract. *The study aimed to highlight quality of life and identify impact differences in balance rehabilitation for patients with lower limb amputation performing hydrokinetic therapy versus kinesiotherapy programmes. The research participants were 16 male patients aged 40-60 years with lower limb amputation for 6-12 months, who were divided into two groups: the hydrokinetic therapy (HKT) group and the kinesiotherapy (KT) group, whose names reflect the contents of rehabilitation programmes implemented over a 2-week period. The study included two testing phases, an initial and a final one, and used the Four Square Step Test to assess balance and the TAPES questionnaire to assess quality of life. Analysis of the results for the Four Square Step Test aimed at balance rehabilitation indicated 6.125 seconds for the HKT group and 6 seconds for the KT group. It is also found that the rehabilitation of balance and quality of life is effectively achieved by implementing both HKT and KT programmes. The research findings highlight that more attention is paid to changes in the medical condition of patients and how they manage different daily situations and use the prosthesis. We can state that the use of the prosthesis and the medical condition determine a better quality of life than the type of rehabilitation programme applied.*

Keywords: *lower limb amputation, hydrokinetic therapy, physical therapy, quality of life, balance.*

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Introduction

Amputation is defined as the intentional surgical removal of a limb, part of a limb or body part. Lower limb amputation is a permanent surgical procedure that leaves major functional, psychological and social sequelae that can influence quality of life (Bussmann et al., 2004).

Depending on the anatomical area (from distal to proximal), lower limb amputations are systematised into: toe amputation, transmetatarsal amputation, Lisfranc amputation, Chopart amputation, Syme amputation, transtibial amputation, Van Nes rotation, knee disarticulation, transfemoral amputation, hip disarticulation and hemipelvectomy (Cristian, 2005).

The specific level of amputation is determined by a multitude of factors: in post-traumatic amputations, the viable tissue determines the level, and following vascular diseases with infection, the level is determined by the unaffected vascular area.

After lower limb amputation, an imbalance develops in the biomechanics and biostatics of the whole body. A missing segment of the lower extremity produces motor deficit in muscle and joint groups, with disruption of functional capabilities due to imbalanced gait patterns. Absence of the amputated segment induces partial and global activity restrictions. "Most of the individual's functional activities require good range of pelvic, hip, knee and ankle motions" (Mohanty et al., 2020), but the biomechanics involved in walking and running are altered after the loss of a limb or part of it. The resulting dysfunctions lead to the onset of disability, which influences psycho-emotional status, independence, quality of life and life expectancy.

Significant changes are also observed in the balance and gait of lower limb amputees with asymmetric weight distribution and a dissymmetrical gait favoring balance losses and falls. Furthermore, the level of amputation plays a decisive role in gait patterns after surgery. The shorter abutment requires greater forces during walking and therefore greater energy consumption (Latanioti et al., 2013).

Postural instability is a major limiting factor in activities of daily living for people with lower limb amputation and is reflected in both static and dynamic aspects of balance. For example, postural stability deficits in transtibial amputees are the result of biomechanical and neurophysiological changes, and altered sensorimotor integration leads to compensatory and adaptive mechanisms (Kolarova et al., 2013). Lower limb amputation is a life-changing event that has an impact on functional, work, social and recreational activities.

Revicki et al. (2009) define quality of life as a broad range of human experiences related to an individual's overall wellbeing. It encompasses the interplay between expectations and the actual subjective experiences, states and perceptions.

Mucsi (2008) refer to subjective perceptions of the effect of a disease or its treatment on a person's general health and quality of life. It includes the physical, psychological and social dimensions of health as assessed by the patient. Health-related quality of life can be used to describe the effects of disease and injury on the quality of life and the effect of clinical interventions on health and general wellbeing. Studies have revealed that quality of life is e closely related to both physical and social aspects of an amputee's life. Therefore, quality of life is an important issue for the large number of patients who may need to cope with severe and chronic disability caused by trauma (Deans et al., 2008; Quigley & Dillon, 2016).

A main goal of rehabilitation is to improve patients' quality of life by reducing their functional limitation and disability. For lower limb amputees, a prosthetic limb has the potential to compensate for loss of mobility and allow them to integrate into their environment to carry out daily and social activities. Quality of life in amputee research is often equated with the ability to walk again, which is why rehabilitation programmes put emphasis on walking independently with the prosthesis (Van de Meent et al., 2013).

Nowadays, the range of motor activities aimed at increasing quality of life has diversified, and people have the possibility to choose according to their preferences, financial status, etc. One of the most pleasant activities is the aquatic one, which can be practised in several forms: swimming, water gymnastics, hydrokinetic therapy etc. (Marinescu et al., 2011).

Hydrokinetic therapy consists of exercises or movements performed with the body in immersion, thus benefiting from the complex action of thermal, mechanical and chemical factors (Cordun, 1999). It maximises the characteristics and advantages of water and has an excellent therapeutic effect (An et al., 2019). Unlike conventional treatment, it does not appear to have noticeable adverse effects (Mooventhan & Nivethitha, 2014).

Balance, strength and proprioception can be trained in the aquatic environment. According to Ehde et al. (2001), water activity is appropriate for the geriatric population, given that water allows for more independent upright positions. These authors claim that, in water, there may be an increase in stimulation and muscle relaxation because patients are less afraid of moving and that water activity can facilitate vestibular inputs. Aquatic exercise can be more suitable than land exercise for people with musculoskeletal impairments. Joint load decreases in relation to the immersion depth.

Body immersion up to the level of the sacral region allows a 54% reduction in weight, thus reducing pressure and stress on the lower extremities. Consequently, aquatic exercise can be a more effective intervention to improve balance for the elderly with significant joint pathology. Warm water has the potential to facilitate blood flow to the joints involved, relax the muscles and temporarily reduce pain. Exercising in water can slow down the rate of falls due to its viscosity and density properties, allowing a person with impaired balance more time to detect postural errors that might lead to a fall.

The health effects of hydrotherapy generally occur as thermal, mechanical and chemical ones, either alone or as mixed effects. Thermal effects are vasodilation, blood flow facilitation and pain reduction, while mechanical effects can be explained by the properties of water such as buoyancy, hydrostatic pressure and resistance. The thermal factor has several advantages: increases superficial blood circulation; induces muscle relaxation; increases the pain sensitivity threshold (an important psychological benefit); stimulates thermoregulation and metabolism; provides a subjective sense of wellbeing. Buoyancy is the force that opposes gravity, and when the body is partially or fully immersed, pain reduction and improved exercise capacity occur due to stress reduction or application of weight to specific body parts. Hydrostatic pressure facilitates blood flow by varying the pressure exerted on the body according to the immersion depth, which results in increased blood flow to major organs (heart, brain and lungs) - Jimenez et al. (2010).

Hydrostatic pressure is directly proportional to the immersion depth and provides the following advantages:

- facilitates venous blood circulation, which in turn helps to reduce stump oedema;
- respiratory muscles oppose resistance during inhalation, which facilitates exhalation;
- sensory stimulation to the water-produced excitants (Chiriac, 2010);
- muscle relaxation due to the increased amount of circulating blood;
- associated with warm water, it reduces the joint pain felt by some participants in aquatic programmes, which increases their ability to mobilise the segment through the full range of motion of the joint concerned.

Once the injury has healed after lower limb amputation, rehabilitation generally focuses on the use of the prosthesis to help patients regain their ability to walk (Ries & Vaughan, 2007).

Methodology

Scope

The *purpose* of this study is to assess the quality of life of patients with lower limb amputations and to create, test two functional rehabilitation protocols with the main objective of improving quality of life.

Objectives

- to highlight the means and methods of work used during the recovery period to improve quality of life but whose effectiveness has not been verified in the national literature;
- to update the existing information with information from the international literature and to test its effectiveness on the Romanian population where the number of amputations is increasing, because there are few reports in the national literature about the rehabilitation of this pathology through hydrokinetic therapy and kinesiotherapy.

Hypothesis

The level of functional recovery (dynamic balance) is regained better in patients who did hydrokinetic therapy compared to patients who practiced kinesiotherapy.

Participants and Procedure

The experimental study included 16 patients in the pre-prosthetic and prosthetic phases, with lower limb amputation as a result of work accidents. They were divided into two equal groups as follows: the experimental group, which performed the hydrokinetic therapy programme, and the control group, which performed the kinesiotherapy programme.

Inclusion criteria were: transfemoral amputation, transtibial amputation, age between 40 and 60 years, age of amputation between 6 and 12 months, male gender.

Exclusion criteria were: amputation level other than thigh and calf, bilateral amputation, other causes of amputation, age under 40 and over 60 years, people with mental problems, hyperthermia, sphincter incontinence, respiratory failure, fear of drowning, chlorine allergy, female gender.

The study took place at the National Institute of Medical Expertise and Work Capacity Recovery in Bucharest, which has a kinesiotherapy room and a hydrokinetic therapy pool equipped for the rehabilitation of amputees.

Rehabilitation protocols for kinesiotherapy and hydrokinetic therapy were applied to patients in the pre-prosthetic and prosthetic phases, and the following objectives were pursued: stamp shaping and maturing, improving muscle strength and endurance, maintaining and increasing joint mobility, retraining balance and coordination, prosthetic gait training, cardiovascular and respiratory training as well as developing ADL (activities of daily living) programmes.

The rehabilitation programme consisting of a kinetic programme included: postures, free active mobilisations, active mobilisations against resistance. The second protocol was represented by hydrokinetic therapy.

The rehabilitation sessions applied to both groups took place 5 times per week over two weeks (during hospitalisation), with each session lasting about 30-45 minutes. Both the kinesiotherapy (KT) and hydrokinetic therapy (HKT) programmes were constantly adapted to the clinical condition of patients. The hydrokinetic therapy programme was applied in a pool with a water depth of 0.5-1.6 m, so the water was at chest level for most patients. The water temperature was 30^0 C with +/-3^0 C. The kinesiotherapy programme was performed in the rehabilitation room within the hospital.

Assessment

To investigate the impact of rehabilitation programmes on patients with lower limb amputation, the present study focused on dynamic balance assessment. Quality of life was assessed using the Trinity Amputation and Prosthesis Evaluation Scale (TAPES).

The Four-Square Step Test (Verma et al., 2014) assesses dynamic balance by a person's ability to step over low objects in several directions: forward, sideways, backward. The test involves the quick transfer of body weight from one foot to the other during changes of direction but also stepping over obstacles. Normal value is considered a score of <24 seconds, which indicates no risk of falling, while a score >24 seconds is associated with impaired balance and risk of falling.

For the specific psychosocial and functional testing of people with limb amputation, the TAPES questionnaire (Gallagher & Maclachlan, 2004) is most commonly used. It includes closed-ended questions (full disagreement, disagreement, agreement, full agreement) and open-ended questions, meeting the requirements of the medical and sociological literature. The examined dimensions focused on the following issues:

- assessment of psychosocial status (15 items); e.g. *I have adapted to wearing the prosthesis.; I feel that I have coped with this trauma etc.*
- functional capacity (8 items); e.g. *More difficult activities, running, sports, weight lifting.; To walk more than 2 kilometres etc.*
- degree of satisfaction with the prosthesis (8 items); e.g. *colour; utility etc.*
- self-reported health status - in the current study, the main question was: *In general, how would you describe your health?*

For this study, the data were processed using SPSS 22, and the statistical parameters used were: mean, standard deviation, mean difference between tests, dependent t-test, independent t-test, Leven‘s test, a 95% confidence interval (CI) with lower and upper bounds. For the present study, a p-value of <0.05 was chosen as reference for statistical significance.

Results

Table 1. *Statistical indicators for the 4-square step test*

	Hydrokinetic therapy group		Kinesiotherapy group	
Statistical parameters / Tests	**It**	**Ft**	**It**	**Ft**
Arithmetic mean	27,62	21,50	28,25	22
Standard deviation	4,62	3,50	4,09	2,43
Minimum	20	15	23	20
Maximum	35	27	35	27
Median	28,50	21,50	28,50	22
Range	15	12	12	7
The coefficient of variability	16,73%	16,28%	14,48%	10,92%

The first group at the initial assessment had a minimum of 20 sec and a maximum of 35 sec, and at the final assessment progressed to a minimum of 15 sec and a maximum of 27. The second group, at the initial assessment a minimum of 23 sec and a maximum of 35, also progressing to the final evaluation to a minimum of 20 sec and a maximum of 27.

The average time (Table 1) in the step test in 4 squares decreased at the final evaluation of the hydrokinetic therapy group by 6.12 sec from 27.62 to 21.50, and in the kinesiotherapy group it decreased by 6.25 sec from 28.25 to 22. In other words, the balance changed from "affected" to "normal". The average values for the walking time in 4 squares of the two groups are shown in Figure 1.

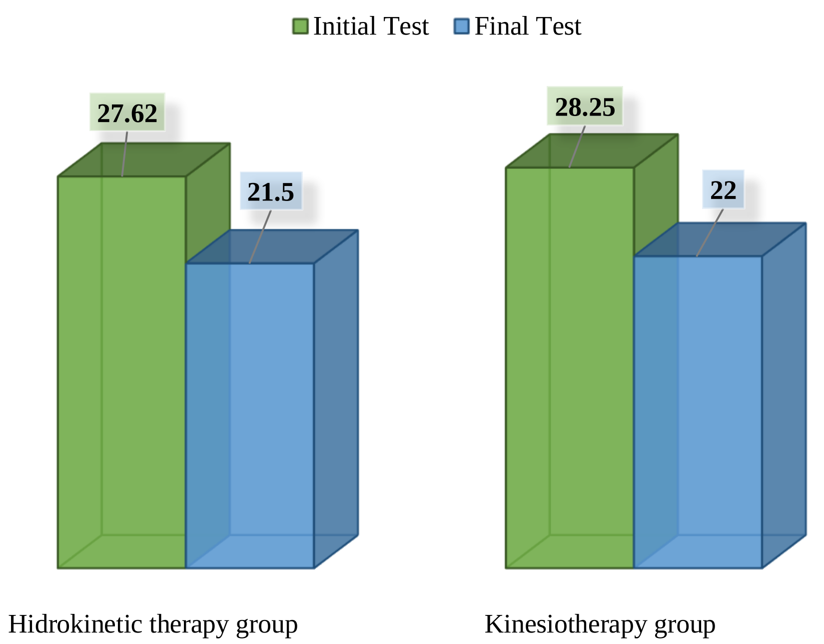

Figure 1. Difference between average initial and final test

Table 2. *Statistical indicators for the 4-square step test - Dependent T-Test*

Statistical parameters	**Hydrokinetic therapy group Ft-It**	**Kinesiotherapy group Ft-It**
Mean difference	-6,12	-6,25
Standard deviation	1,80	2,20
95% CI (lower/upper bounds)	-4,61; -7,63	-4,15; -7,84
Test-t dependent value	-9,583	-7,700
P value	,000	,000

The time values are dispersed relatively homogeneously in both evaluations. The difference in means is within the confidence interval (-4.61; -7.63) for the hydrokinetic therapy group and (-4.15; -7.84) for the kinesiotherapy group. The difference is significant, significance threshold $p<0.001$, for both groups. For the hydrokinetic therapy group $t=9.583$, and for the kinesiotherapy group $t=7.700$.

Table 3. *Statistical Indicators for the 4-Square Step Test - Independent T-Test*

Statistical parameters	**Hydrokinetic therapy group vs. Kinesiotherapy group It**	**Hydrokinetic therapy group vs. Kinesiotherapy group Ft**
Mean difference	-,62	-,75
Standard deviation error	2,18	1,50
95% CI (lower/upper bounds)	-5,31; 4,06	-3,98; 2,48
Test-t independent value	-,286	-,497
Test-t independent p value	,779	,627
Levene's Test F value	,031	,517
Levene's Test p value	,863	,484

The difference between the averages of the two groups at the initial evaluations is 0.62 sec and at the final evaluations is 0.75 sec with a standard deviation error of 2.18 and 1.50, respectively. The confidence interval for the difference in means between groups is (-5.31; 4.06) at initial testing and at the final testing it is (-3.98; 2.48). The independent t-test for equal variances reveals a statistically insignificant difference in means, $p=0.779$ for $t=-,286$ at initial evaluation and $p=0.627$ for $t=-,497$ at final evaluation.

There are no positive differences between the two groups in terms of dynamic balance at the end of the intervention program, but the majority of subjects registered a progress after rehabilitation.

In order to measure the respondent's quality of life, TAPES was used as a research tool applied to people who carry out rehabilitation programs. The tool is built on two levels, the first part includes indicators that evaluate the general condition of the respondents and the extent to which they have adapted to the changes produced by the medical condition and the way in which they manage different everyday situations. The second part of the questionnaire focuses on the respondent`s attitudes regarding the challenges of the medical condition and their impact on life, focusing on the effects of the disability on the person.

The first analysed variable measures on a scale from 1 (full disagreement) to 4 (full agreement) different aspects of the respondents' lives (Figure 2), so even if all respondents believe that over time they accept their prosthesis more and more, some of them are not still adapted to wearing it (5 participants), and most believe that the prosthesis limits the amount of work they can do (12), as well as the activities and type of work they want (12). Over time, the respondents do not feel embarrassed if someone looks at the abutment or the prosthesis or asks them about it, accepting to talk about it.

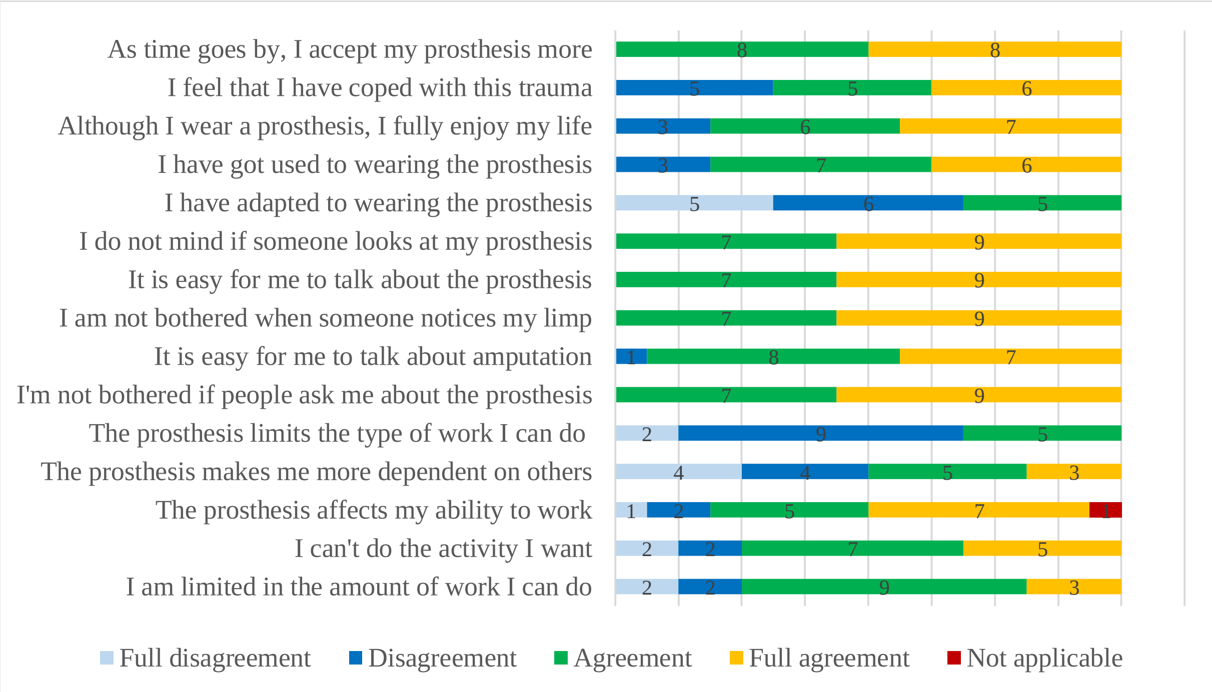

Figure 2. Perception of how the prosthesis and medical condition influence different aspects of patients' lives

Respondents' perceptions of how they feel limited in their daily activities were assessed by analysing 8 items measured on a scale of 0 (not limited at all) to 2 (significantly limited), thus calculating the mean values for each indicator as well as the overall mean score (1.24 in the range from 0 to 2). Table 4 and Figure 3 highlight that respondents feel most limited when they have to run to catch a means of transport (mean: 1.62) or to cover a distance longer than 2 km, but they feel less constrained by their condition when performing activities of interest such as hobbies (mean: 0.69).

Table 4. *Mean score of perceptions regarding the limitation of daily activities*

	More difficult activities (running, sport, lifting)	**Climbing several floors by stairs**	**Running to catch a means of transport**	**Light sports activity**	**Walking more than 2 km**	**Walking 100 m**	**Performing activities of interest**	**Going to work**
Mean	1.44	1.31	1.62	1.19	1.56	.81	.69	1.31
No. of patients	16	16	16	16	16	16	16	16
Std. deviation	.629	.704	.500	.655	.512	.544	.602	.946

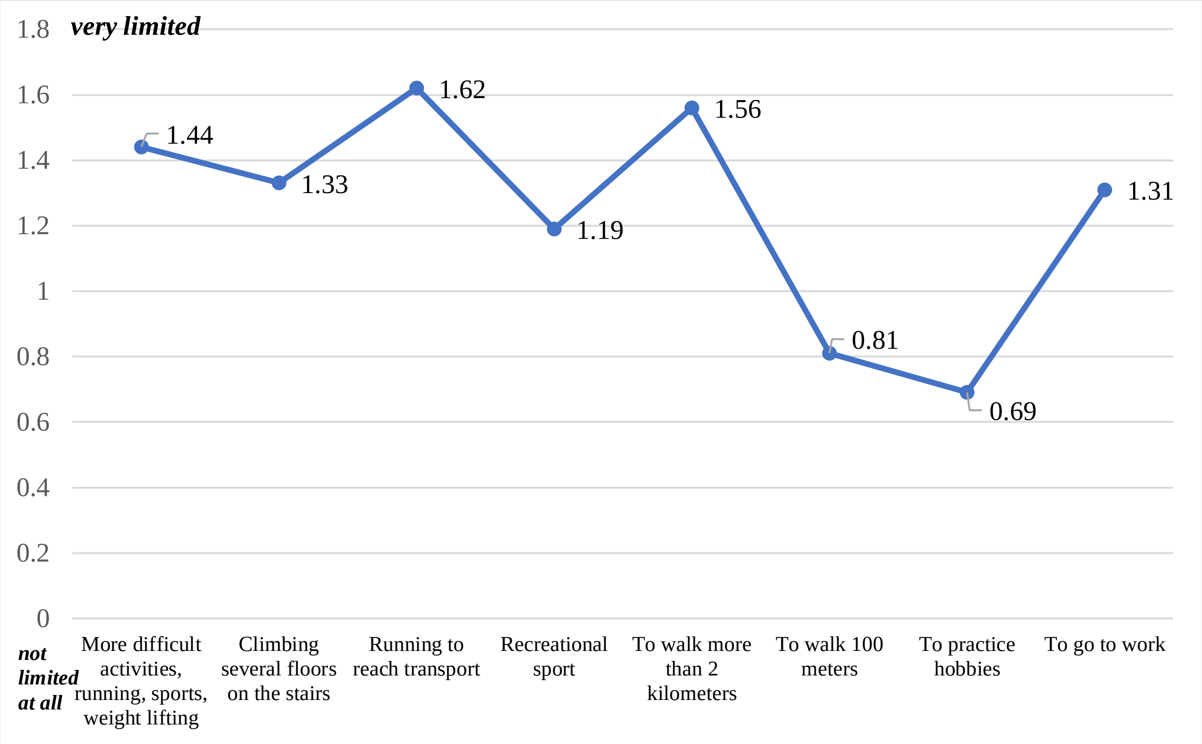

Figure 3. Mean score of perceptions regarding the limitation of daily activities

Respondents expressed their satisfaction with different aspects related to the prosthesis, indicating how satisfied or dissatisfied they were with it according to a scale of 1 to 3. Figure 4 highlights that the weight of the prosthesis produces the most dissatisfaction, followed by the comfort offered by wearing the prosthesis and its external appearance, while the utility of the prosthesis brings the greatest satisfaction among the surveyed respondents.

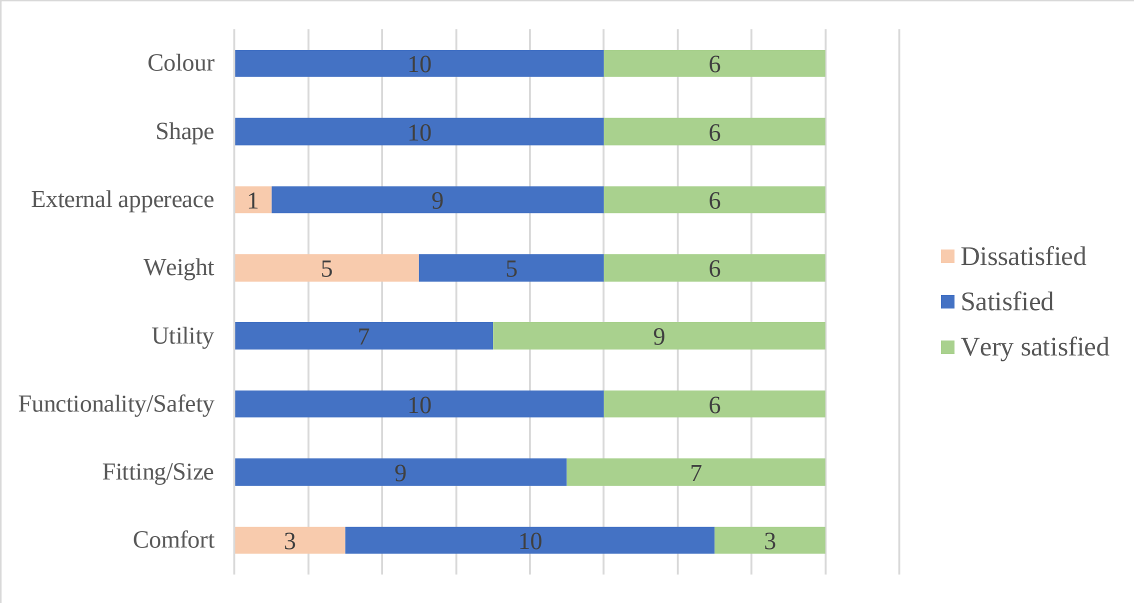

Figure 4. Satisfaction with different prosthesis-related aspects

Nine out of 16 respondents claimed that they have residual pain, which is uncomfortable (1 person), stressful (4) and very strong (4). These affecting the social activity moderately (4), quite a lot (4) and a little (1). 11 subjects out of 16 have phantom limb pain, describing it as uncomfortable (4), stressful (5) and very painful (2), the majority being affected by this aspect socially (9). In addition to these, 6 respondents claimed that they have other medical problems such as diabetes, hypertension, vision problems, conditions that they describe as stressful.

Overall satisfaction with the prosthesis was measured by respondents expressing their opinion on a scale from 1 (very dissatisfied) to 10 (very satisfied). Table 5 presents the correlation between the health status of the respondents (expressed on a 10-point scale, where 10 = the highest value in terms of perceived health) and the general satisfaction with the prosthesis.

Table 5. *Correlation between health status and satisfaction with prosthesis*

		Health status	Satisfaction with the prosthesis
Health status	Pearson Correlation	1	.625**
	Sig. (2-tailed)		.010
	N	16	16
Satisfaction with the prosthesis	Pearson Correlation	.625**	1
	Sig. (2-tailed)	.010	
	N	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

In Table 5 we can observe the state of health of the respondents is positively associated with the satisfaction with the prosthesis, so the better they believe they have a state of health, the more satisfied they are with the prosthesis they wear - correlation coefficient r = 0.625, in the range -1, +1. The effect size index r^2 = 0.39, emphasizing a moderate to strong link between variables. The lower limit = 0.188, while the upper limit = 0.855 (95%).

Discussion

This study aimed to identify the impact of kinesiotherapy and hydrokinetic therapy programmes on the rehabilitation of balance and quality of life in the pre-prosthetic and prosthetic periods.

We believe that the specific results obtained in our study can expand the level of knowledge of specialist therapists on the role and impact that kinesiotherapy but especially hydrokinetic therapy programmes can have in the process of motor and clinical-functional rehabilitation of patients with lower limb amputation.

In terms of quality of life, the analysed variables were related to the rehabilitation techniques in order to measure their impact on improving the medical condition and life of the surveyed patients. Respondents who believe they enjoy very good health have a higher mean score for acceptance and adaptation of their medical condition to various aspects of life, while those who rate their health status as poor are the most dissatisfied with how they manage prosthesis.

Physical activity has beneficial effects on muscle strength and endurance in older adults. Frailty is an indication to begin exercise to improve functional capacity. Multicomponent exercise interventions (including aerobic, strength, balance and flexibility exercises) reduce the incidence, prevalence and severity of frailty and improve the patients' functional capacity and overall mobility.

Physiotherapy in general and the specific exercise programmes offered during rehabilitation vary depending on the goals set out and individual clinical characteristics. For people undergoing lower limb amputation, medical complications can delay preparation for prosthetic fitting and extend the recovery process. Besides the rehabilitation environment, other variables that influence the rehabilitation process include medical conditions and clinical characteristics such as age, aetiology of amputation and level of amputation. Many of these variables, although beyond the control of the individual and the clinician, can affect the rehabilitation process and outcome. Thus, modifiable variables such as the exercise programme selected to improve gait performance could have an important impact on the individual's recovery after lower limb amputation (Wong et al., 2016).

Kinesiotherapy for amputees has the following effects (Dragotoiu et al., 1987): adaptation to new static and dynamic conditions, physical development, increased breathing capacity, regaining the upright position and balance, stump preparation for the prosthesis, regaining walking ability in indoor and outdoor spaces. The goal of balance exercises is to improve the patient's functional capacity and ability to walk to prevent falls.

Analysis of the study results highlights statistically significant differences between the final and initial testing in the Four Square Step Test for balance assessment. The design, adaptation and application of a hydrokinetic therapy programme for patients with lower limb amputation in the pre-prosthetic and prosthetic periods represent some novel aspects that, according to the study findings, will contribute to balance improvement and rehabilitation due to the properties of the aquatic environment and the multiple possibilities of practice.

Aquatic therapy is considered a safe and effective tool in treatment because immersion in boiled water decreases joint overload and pain symptoms and improves functional capacity and quality of life (Alcalde et al., 2017).

As a result of physiological effects induced by immersion, aquatic therapy is an exceptional way of physical training for any person, providing the opportunity to adjust programmes and methods to the patient's condition (Murgu et al., 2007).

Using the unique properties of water can facilitate optimal session planning to support and enhance a functional rehabilitation programme. Major applied benefits of aquatic therapy include: reducing pain and oedema, improving joint mobility, retraining gait, maintaining and/or developing cardiovascular fitness, and developing coordination (Cutler, 2017).

The physiological effects induced by immersion are the following (Murgu et al., 2007): a) effects on the cardiovascular system - increased blood volume in the heart by facilitating venous return (immersion up to the neck level leads to an increase in blood volume of up to 60%), increased myocardial contraction force by increasing the volume of blood reaching the heart (Starling's law), increased stroke volume by approximately 35%, increased cardiac output and heart rate (as a result of increased stroke volume); b) effects on the respiratory system: reduced lung volume and exhaled air volume due to the pressure exerted on the chest by the fluid environment, more reduced pulmonary compliance and increased pressure in the pleural cavity (when the human body is immersed up to the neck level, breathing difficulty increases by 60%), increased respiratory effort (being a very good method for breathing exercises); c) effects on the musculoskeletal system: increased blood flow at muscle level by almost three times; increased elimination of toxic metabolites from muscles; increased rate of muscle metabolism and local oxygen consumption.

Research on patients with lower limb amputation has mainly focused on aspects related to pain therapy, the process of adaptation to the prosthesis, the improvement of motor ability and functional capacity, the psychological impact, the optimisation of patients' quality of life, social and professional integration (Burger & Marincek, 2007).

The earlier specialised exercise programmes are applied, the higher the effectiveness of motor and functional rehabilitation (Schafer et al., 2018).

Conclusion

The results obtained improved following the implemented rehabilitation programs. According to the final evaluation, a progress in the functional capacity of each subject was highlighted, but the difference between the averages of the two groups in the final motor evaluations is small, highlighting the average time in The Four-Square Step Test decreased of the hydrokinetic therapy group by 6.12 sec from 27.62 to 21.50, and in the kinesiotherapy group it decreased by 6.25 sec from 28.25 to 22. In other words, the balance changed from "affected" to "normal". Based on the collected data, after the final evaluation, the results being statistically insignificant following the independent t-test we can reject the hypothesis that the level of functional recovery (dynamic balance) is regained better in patients who did hydrokinetic therapy compared to patients who practiced kinesiotherapy. We can state that the use of the prosthesis and the medical condition determine a better quality of life than the type of rehabilitation programme applied.

The properties of water can be used to implement an aquatic therapy programme that, if properly planned, facilitates the development of an improved functional rehabilitation programme after amputation.

The research findings highlight that more attention is paid to changes in the medical condition of patients and how they manage different daily situations and use the prosthesis.

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Institutional Review Board Statement: The research was conducted according to the principles stated in the Declaration of Helsinki. Written informed consent was obtained from all patients. The study was approved by the Ethics Committee of the National University of Physical Education and Sport in Bucharest, with no. 112/SG.

Informed Consent Statement: The participants provided their written informed consent to participate in this study.

Data Availability Statement: Data are available upon request to the contact author.

Conflicts of Interest: The authors declare no conflict of interest.

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