Assessment of Perception in Lower Limb Amputees of Rehabilitative Physical Therapy Complemented with Virtual Reality

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KEYWORDS

Lower Limb Amputees, Rehabilitative Physical Therapy, Virtual Reality, Perception Assessment

ABSTRACT

The present essay describes the perceptions and attitudes of a group of 111 lower limb amputees who have been on a physical therapy and rehabilitation program intended to achieve a final adaptation of a Lower limb prosthesis and accepted to add a virtual reality-supported therapy tool as a complementary reinforcement. The program started up attending an instructional training session based on a desktop non-immersive 360 virtual reality training video. In the video an avatar performs 5 series of 3 timed repetitions of the following routine: Kicking, Squatting, Cycling, March . At the end each participant filled a questionnaire of 5 items asking for perceptional attitudes as: Utility, Gratification, assimilability, Recommendability and understandability. the results found high rates of general acceptability and receptibility. the bivariate analysis was found with no statistical significance.

1. Introduction

Virtual reality and augmented reality programs have been applied in different fields, from the military and industrial [1] to more recently in computer science, marketing and medicine [2][3]. It is envisaged that these programs, thanks to the continuous development and improvement they have had, could become an alternative of great relevance to achieve the objectives in the rehabilitation of patients who face a wide range of mental, psychological, motor and musculoskeletal diseases and affectations [4][5]. This therapeutic approach, supported by technological evolution, has proven effective in people of all ages, providing significant benefits as a complement to their specific treatments [6][14]. For people who have suffered traumatic or degenerative amputations in their lower extremities, resuming their lives and achieving full performance represent monumental challenges. These challenges are manifested both in the rehabilitation process and in the adaptation and training for the use of prostheses, facing significant barriers both from the perspective of supply and demand. These barriers can hinder the optimal and rapid recovery of these patients [15][16].To what extent certain barriers, such as geographical, economic, supply, administrative, cultural and cognitive barriers, can be overcome through unique or complementary strategies based on the application of virtual reality is a question still unanswered, in Colombia exhaustive research has not been carried out to date. This work seeks to present a first approach to evaluate the perception of patients with lower limb amputation of virtual reality-based therapies during the process of recovery and adaptation of prostheses. The present study focuses on investigating the degree of acceptance by patients and the potential benefits derived from the integration of virtual reality aids in the rehabilitation process.

Methods

We conducted a descriptive cross-sectional study. The population was made up of patients treated in the rehabilitation and prosthetic adaptation program of a Health Service Provider Institution in Medellín, Colombia between September 1, 2022 and February 28, 2023. The participants included were patients with traumatic or degenerative amputation of the lower limbs, unilateral and/or bilateral, of any age, linked to any type of insurance among those existing in the health system created by Law 100 of 1993, who attended the rehabilitation program and patients who were in the preparation stages. Prosthetic design and fitting. We excluded participants with incomplete data.

The Health Service Provider Institution from which the participants were selected is an institution with an outpatient consultation service that focuses on the care of patients with specific needs of movement and locomotion, rehabilitative management, workshop, manufacture and adaptation of orthoses and prostheses.Participants were selected by non-probabilistic critical sampling, according to the investigator's clinical judgment. Participants who met the eligibility criteria authorized their participation through informed consent, and for patients under 20 years of age, it was their guardians who consented to the patient's participation. The study consisted of carrying out a test that is part of the Kinet project designed by the Ginetec group of the Pontifical Bolivarian University. The Kinet project consists of two stages, however, this study focuses on the evaluation of the first stage where the patient performs a visual and physical experience by observing an avatar in the metaverse that simulates the exercise routine aimed at the physical conditioning of the three large joints of the lower limbs: hip, knee and foot. with routines composed of repetitions of squat, knee kick or oscillation, static cycle and walk, with a predetermined scoring system and continuous incentive for auditory and visual feedback. The second stage consists of a total immersion experience with the use of the Oculus Rift S ® device (Meta Platforms, Menlo Park, California, USA) with connection to the computer's video card and real-time motion capture sensors, this second stage is not evaluated in the present study.For data collection, the sociodemographic characteristics were questioned directly to the patient, and after the test was carried out, the participants were asked to fill out a form specially designed by the researchers to evaluate the perception of virtual reality therapy. The form included 5 questions that evaluate the aspects of usefulness defined as the degree of perceived benefit, gratification that consists of the playful benefit of the experience, recommendability and comprehensibility which is the degree of difficulty in the execution of the routine and assimilability understood as the degree of similarity between the virtual experience and the real physical exercise. The answers to the questions were on the Likert scale, which is a qualitative ordinal scale that allows respondents to express in a score of 1 to 5 the usefulness, gratification, recommendability, comprehensibility, and assimilability of the test. Being 1 not at all and 5 extremely. The details of the form and the scale of responses can be found in supplementary material annex 1. We performed a univariate analysis. Qualitative variables were reported using absolute and relative frequencies; for quantitative variables, their adjustment to normal distribution was evaluated using the Kolmogorov Smirnov test. We consider a value of $p < 0.05$ to be significant. Variables with normal distribution were reported with the mean and standard deviation, and variables with non-normal distribution with median and interquartile range (IQR). For the age variable, we categorized it at intervals of 20 years. For the bivariate analysis, each of the possible combinations was taken into account, establishing relationships and trends through the levels of significance obtained, for the correlative analysis of the categorical variables the Chi-square test was used, and for the analysis of the existence of correlative strength, Spearman's Rho test was used.

All analyses were performed in Statistical Package for Social Sciences (SPSS version 22) and Statgraphics Plus 4 software. This study was reviewed and approved by the research ethics committee of the Health Service Provider Institution.

Results and Discussion

Table 1. Characteristics of the participants (n = 111)

Feature	n (%)
Age, in years	
Under 20 years old	11 (9.7)
Between 20 and 39 years old	27 (23.9)
Between 40 and 59 years old	41 (36.3)
Over 60 years of age	32(28.3)
Men	91(82)
Women	20(18)
Type of insurer	

ARL*	12 (10.8)
Special regime	13 (11.7)
SOAT**	2 (1.8)
Subsidized regime	5 (4.5)
Contributory Regime (EPS)***	63 (56.7)
Contributory regime (other EPS)	16 (14.4)
Amputation height	**n (%)**
Transtibial	56(50.5)
Transfemoral	52(46.8)
Transtarsus	1(0.9)
Knee disarticulation	2(1.8)

***ARL:** occupational risk administrator.

**** SOAT:** compulsory traffic accident insurance.

EPS: health-promoting entity.

Table 2. Score of the items evaluated (n = 111)

Item	Median (IQR)*
Usefulness	4.00
Gratification	4.40
Recommendability	4.00
Comprehensibility	5.00
Assimilability	4.00

***RIC: Interquartile Range**

Table 3. Bivariate analysis (n = 111)

Feature	X2 calculated	X2 Critical	Gl*	Pvalor
Age				
Usefulness	9.42	23.58	9	0.005
Gratification	9.84	23.58	9	0.005
Recommendability	5.71	23.58	9	0.005
Comprehensibility	5.17	18.54	6	0.005
Assimilability	5.26	18.54	6	0.005
Sex				
Usefulness	2.93	10.597	3	0.005
Gratification	8.08	12.83	3	0.005
Recommendability	5.13	12.83	3	0.005
Comprehensibility	1.07	10.59	3	0.005
Assimilability	1.75	10.59	2	0.005

***GL: Degrees of Freedom**

Table 4. Correlation analysis (n = 111)

Feature	Correlation coefficient	Pvalor
Age		
Usefulness	-0.052	0.585
Gratification	-0.057	0.550
Recommendability	-0.023	0.808
Comprehensibility	-0.011	0.911
Assimilability	-0.007	0.938
Sex		
Usefulness	0.14	0.118
Gratification	0.17	0.119
Recommendability	0.162	0.089
Comprehensibility	0.010	0.915
Assimilability	-0.03	0.734

Table 5. Intervariable Relationships

	Relationship between Age and variables				Relationship between sex and variables		
		X^2 calculated	X^2 Critical	Good luck, significance	X^2 calculated	X^2 Critical	GL, significance
Gratification		9.847	23.589	9, 0.005	8.086	12.838	3,0.005
Recommendability		5.71	23.589	9,0.005	5.136	12.838	3,0.005
Comprehensibility		5.17	18.548	6,0.005	1.076	10.597	3,0.005
Usefulness		9.42	23.589	9,0.005	2.93	10.597	3,0.005
Assimilability		5.268	18.548	6,0.005	1.755	10.597	2,0.005

Table 6. SPSS statistical descriptions

Tabla 6. Descriptivos de cada variable

	Utilidad	Gratificacion	Recomendabilidad	Comprensibilidad	Asimilabilidad
Media	4.26	.26	4.30	4.57	4.23
Mediana	4.00	4. 400	4.00	5.00	4.00
Desviación Estándar	.735	.710	.695	.566	.628
Curtosis	.177	.452	.728	-.217	-.580
Error de Curtosis	.455	.455	.455	.455	.455

Table 7.Bivariate correlations run in SPSS

Correlaciones Bivariadas

		Utilidad	Sexo	Sexo	Recomendabilidad	Comprensibilidad	Sexo	Sexo	Asimilabilidad	Utilidad	Edad	Edad	Gratificación	Edad	Recomendabilidad	Edad	Comprensibilidad	Edad	Asimilabilidad
Spearman's rho	Correlation Coefficient	1.000	.149	1.000	.162	1.000	.010	1.000	-.033	1.000	-.052	1.000	-.057	1.000	-.023	1.000	-.011	1.000	-.007
	Sig. (2-tailed)	.	.118	.	.089	.	.915	.	.734	.	.585	.	.550	.	.808	.	.911	.	.938
	N	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111
	Correlation Coefficient	.149	1.000	.162	1.000	.010	1.000	-.033	1.000	-.052	1.000	-.057	1.000	-.023	1.000	-.011	1.000	-.007	1.000
	Sig. (2-tailed)	.118	.	.089	.	.915	.	.734	.	.585	.	.550	.	.808	.	.911	.	.938	.
	N	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111	111

annex supplementary material (see Excel sheet)

We included 111 patients who met the eligibility criteria. The median age was 3, corresponding to the age group between 40 and 60 years, interquartile range RIC 2 (age group between 20 and under 40 years). 41 participants (36.3%) were in the age range between 40 and 59 years, 32 (28.3%) were over 60 years old, 27 (23.9%) were in the range of 20 and 39 years and 11 (9.7%) were under 20 years old. Regarding sex, 91 (82%) were men. (see table 1). The median utility score was 4.0 (IQR:1), for gratification it was 4.4 (IQR:1), recommendability 4.0 (IQR:1), comprehensibility 5.0 (IQR:1) and assimilability 4.0 (IQR:1). (See Table 2). All the items studied, including the independent variables (sex, age), met normality criteria based on the Kolmogorov Smirnov test (see supplementary material).

Of the 111 participants surveyed, 39% found the experience extremely rewarding and 49% found the VR experience very rewarding. According to gender, 34% of men considered the experience extremely rewarding, 52% very rewarding, while in women 64% reported it as extremely rewarding and 36% very rewarding. In the bivariate analysis, when evaluating the relationship between age group and gratification, we found a non-statistically significant association (p= 0.005). And the relationship between sex and the degree of gratification was also not statistically significant (p= 0.005). In terms of recommendability, 41% rated the experience as extremely recommended, 49% highly recommended. Taking into account gender, 37% of men and 59% of women find it extremely recommended, while 51% of men and 41% of women find it highly recommended. When analyzing ages and recommendability, we found that the relationship was not statistically significant (p=0.005), just as the relationship between sex and recommendability was not statistically significant (p=0.005).

The degree of comprehensibility was rated as extremely understandable in 60% and very understandable in 36% of the participants. Considering by sex, 61% of men and 59% of women found the experience extremely understandable, while 37% of men and 41% of women found it very understandable. When evaluating the relationship between age group and degree of comprehensibility, the relationship was not statistically significant (p = 0.005), nor was sex and degree of comprehensibility (p = 0.005). The usefulness of the virtual reality experience perceived by patients was rated as extreme usefulness in 41% and 43% as very useful. 30 and 37% of men rated it as extremely helpful and very helpful respectively, and 54.6 and 40.9% of women rated it as extremely helpful and very helpful respectively. When the differences by age group were evaluated, the association was not statistically significant between age group and perception of usefulness (p= 0.005), with a similar result for the relationship between sex and perception of usefulness (p = 0.005).

Regarding the degree of assimilability between the virtual experience and conventional therapy, given that this item evaluates the similarity and complementarity rather than the degree of substitutability that exists between both modalities since in practice they should not be exclusive, 33% considered it as extremely assimilable and 56% as very assimilable. According to sex, 36% and 53% of the men found the experience to be extremely assimilable and very assimilable, respectively, and 23% of the women reported it as extremely assimilable and 68% as very assimilable. When evaluating the relationship between sex and assimilability, it was not statistically significant (p=0.005) and with respect to the differences in the perception of assimilability and age group, they were not statistically significant (p= 0.005).

We evaluated the correlation of age and each of the components that evaluated the perception of the virtual reality experience. For this, Spearman's correlation coefficient was applied as a statistical method and we found that there is no correlation between age and any of the evaluated components (gratification, recommendability, comprehensibility, usefulness and assimilability). When evaluating the correlation of sex with each component, no statistically significant correlation was found either (p=0.005). Undoubtedly, the low coefficients indicate that other types of variables not analyzed in this work respond to the high receptivity to the virtual reality program. (See Tables 3 and 4). the total collection of information and the global analysis of the data included in the SPSS program can be consulted in tables 5, 6, 7 and annex of supplementary material. In this descriptive, cross-sectional study, we evaluated the perception of 111 patients with lower limb amputation of virtual reality-based therapies during the process of recovery and adaptation of their prostheses. We found that for comprehensibility the median score was 5.0 and for the rest of the items evaluated it was 4.0, which demonstrates a high receptivity and acceptability to the introduction of virtual reality aids to the conventional rehabilitation program of the patient in the mastering stage and use of the prosthetic solution for amputated lower limbs. The ease of execution, and the degree to which the virtual scenario recreates the real everyday experience, is also perceived positively by most patients. The playful component of the virtual training, the feedback from the therapist and the personalization of the training routine as well as the automatic reward system for the correct execution of the virtual program are characteristics that facilitate the initial acceptance and enthusiasm obtained in this cohort.

We did not find significant differences in the comprehensibility item in relation to age, given the existence of barriers to acceptance and technological adaptation that have been observed in studies where virtual reality has been used in elderly individuals [9]. In the case of our country, we find dissimilar situations in terms of access to services, the opportunity for care, and continuity of treatment, which in general have high satisfaction rates in urban centers, but which suffer from significant shortcomings in the most remote geographies of our territory. The premise that we have considered here, is to improve the rates through decentralization of the rehabilitation of amputee patients through the application of therapies based on low-cost virtual reality, supervised synchronously or asynchronously and remotely, with which some barriers, among others, geographical and economic barriers, could be overcome, resulting in the optimization of rehabilitation times and prosthetic adaptation.Limitations and strengths: ours is a local study with no certain possibility of extrapolation, with non-probabilistic sampling, which privileged the collection of data from patients from the most agile and efficient care regimens, which are those that usually establish agreements with the type of entity where the study was proposed.

Applicability: among the benefits that can be expected, we could list the ease of carrying out the practices at home, either with synchronous or asynchronous supervision by the group of therapists, freeing up resources as well as valuable time to be used in parallel activities, whether administrative, care or research. the reduction of costs by reducing the pressure on the agendas of mandatory intra-institutional execution person/person, and logically the adaptive cognitive advantages offered by multisensory stimulation and the iterative nature of virtual reality practice.

Conclusions

Multiple articles have pointed out the shortcomings in the implementation and compliance of programs designed for the rehabilitation of patients with lower limb amputations both locally [17] and globally [18]. Depending on social, geographical, and personal contexts, there are barriers to care, both from the supply and demand levels, as well as limitations in the psychological/attitudinal and cognitive/perceptual spheres that affect adherence to programs and clinical outcomes[16],[19]. In Colombia, especially in geographically remote regions and in lower-income populations, these barriers are even greater. Hence the importance of adopting easily accessible and cost-effective strategies that lead to remedying the lack of adherence and improving the effectiveness of rehabilitation that allows reducing the time of mastering of the prosthesis and the return to work. The general acceptability of virtual reality programs demonstrated by the present study, although not extrapolated to the general population and only limited to the group of participants included, suggests a potential role for the implementation of virtual reality rehabilitation programs in populations with lower limb amputation for various reasons. Its characteristics of accessibility, low cost, ease of monitoring, remote feedback, evaluation and customization of goals and routines, the gamification component with incentives derived from playfulness, motivation and multisensory iterativity are some factors that play in favor of virtual reality programs. The next step should be taken in studies that evaluate the impact and benefit of these programs, taking into account aspects ranging from administrative, economic, care, psychological, personal, social to the biomechanical analysis of gait as long as the use of the prosthesis is effectively mastered in its kinetic domains that include muscle strength and articular and kinematic moment that encompasses cadence, posture, angular and longitudinal displacement.

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