Cost-effectiveness analysis of two rehabilitation plans after primary total knee arthroplasty of individuals aged 65 and over: an economic evaluation

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ABSTRACT

Introduction – Knee arthroplasty is one of the most frequent surgical procedures worldwide. Physiotherapy is widely recommended following surgery. Health systems are facing enormous financial constraints – in Portugal, for example, health expenditure has been steadily increasing and accounted for 11.2% of the Gross Domestic Product (GDP) in 2021 – so it is essential to conduct economic evaluation for resource allocation[1-3]. **Objective** – To compare two different rehabilitation plans in individuals aged ≥65 following primary Total Knee Arthroplasty (TKA). **Methods** – A single-centre experimental study with pre-post intervention assessment of a consecutive sample of two randomized groups: Group 1 (*n*=15) received face-to-face physiotherapy twice per week, supplemented by a home exercise program, and Group 2 (*n*=9) received face-to-face physiotherapy three times per week without additional exercises. Both groups received treatment for five weeks. The effectiveness was measured through individual subcomponents. Pain and function were evaluated by the Oxford Knee Score (scale 12-60 points). Active range of motion (AROM) for knee flexion and extension was measured in degrees with a goniometer. Lower limb muscle strength was measured by counting the number of stands in accordance with the 30s Chair Stand Test. Comparison of effectiveness between the two groups was conducted using parametric and non-parametric tests. The cost of each plan was calculated using the Portuguese Complementary Diagnostic and Therapeutic Means (MCDT)

price list. Economic comparison was made by calculating the incremental cost-effectiveness ratio (ICER). **Results** – Both groups achieved improvements in all effectiveness indicators, with Group 1 showing better outcomes (overall average Group 1=88% versus Group 2=44%). The resulting ICER of € -38.82/effectiveness unit was favourable to Group 1. **Conclusion** – The Group 1 rehabilitation plan was the cost-effective alternative over the comparator, highlighting a potential way to optimize health resources in the hospital department where the study was conducted.
Keywords: Knee arthroplasty; Physiotherapy; Home based exercises; Economic evaluation; Cost-effectiveness analysis.

Análise de custo-efetividade de dois planos de reabilitação pós-artroplastia total primária do joelho em indivíduos com 65 anos ou mais: um estudo de avaliação económica

RESUMO

Introdução – A artroplastia do joelho é uma das cirurgias mais comuns em todo o mundo. Após a cirurgia, a fisioterapia é largamente recomendada. Num contexto em que os sistemas de saúde enfrentam enormes constrangimentos financeiros – em Portugal, por exemplo, a despesa da saúde tem vindo a aumentar de forma constante, representando 11,2% do Produto Interno Bruto (PIB) em 2021 –, é fundamental fazer estudos de avaliação económica para alocação de recursos. **Objetivo** – Comparar dois planos de reabilitação diferentes em indivíduos de idade ≥65 anos após artroplastia total do joelho. **Métodos** – Estudo unicêntrico, do tipo experimental clássico, com a avaliação antes e após intervenção, de uma amostra consecutiva de dois grupos aleatorizados: o Grupo 1 (*n*=15) recebeu fisioterapia presencial duas vezes por semana, complementada com um programa de exercícios em casa, e o Grupo 2 (*n*=9) recebeu fisioterapia presencial três vezes por semana, sem exercícios adicionais. Ambos os grupos receberam tratamento durante cinco semanas. A efetividade foi medida por subcomponente. Dor e funcionalidade foram avaliadas usando o *Oxford Knee Score* (escala de 12 a 60 pontos). As amplitudes de movimento do joelho em flexão e extensão, ativas, foram medidas em graus com goniómetro. A força muscular foi medida contando o número de levantes da cadeira conforme o *30s Chair Stand Test*. A comparação da efetividade entre grupos foi feita através de testes paramétricos e não-paramétricos. O custo de cada plano de reabilitação foi calculado com recurso aos preços das tabelas de meios complementares de diagnóstico e terapêutica em vigor.

A comparação económica foi feita pelo cálculo do rácio custo-efetividade incremental (RCEI). **Resultados** – Ambos os grupos apresentaram melhorias em todos os indicadores da efetividade, com o Grupo 1 a revelar melhores resultados (média do Grupo 1=88% *vs* Grupo 2=44%). O resultado do RCEI de € -38,82/unidade de efetividade foi favorável ao Grupo 1. **Conclusão** – O plano de reabilitação do Grupo 1 foi custo-efetivo relativamente ao comparador, apontando um caminho potencial para otimização de recursos no hospital onde decorreu o estudo.
Palavras-chave: Artroplastia do joelho; Fisioterapia; Exercícios domiciliários; Avaliação económica; Análise custo-efetividade.

Introduction

Knee arthroplasty is one of the most common and effective surgical procedures worldwide[4]. Rehabilitation, especially focusing on physiotherapy and exercise, is widely recommended after surgery. When initiated as early as possible, it optimizes outcomes in both the short and medium term[5-11].

The main indication for surgery is the occurrence of Knee Osteoarthritis (KOA) at the most severe stage of the disease[4,12]. This disease has a general prevalence in the Portuguese adult population of 12.4%[13]. The population ageing and the increase in obesity are two of the main risk factors for KOA and anticipated that the burden of this condition will put upward financial pressures on health systems[14-17]. Considering the enormous financial constraints that health systems face, it is essential to conduct evaluation studies for resource allocation.

Among the various types of economic evaluation studies in the health sector, cost-effectiveness analysis (CEA) stands out[18]. Infarmed-National Authority for Medicines and Health Products – the Portuguese agency responsible for the Health Technology Assessment process – recommends CEA for economic evaluation studies in the health sector[19].

At the hospital where the study took place, the rehabilitation process, involving the intervention of a physiotherapist, begins the day after TKA. Depending on their rehabilitation needs, patients are referred to start outpatient physiotherapy after being discharged from the hospital. This usually involves one to three courses of treatment sessions, each lasting five weeks and occurring three times a week.

The main motivation for this study was to determine whether it would be possible to achieve better therapeutic outcomes with an alternative rehabilitation plan that would also be less costly for the hospital and patient.

Therefore, the research question for this study was: Is a 5-week rehabilitation plan of twice-weekly face-to-face physiotherapy complemented with a home-based exercise program

cost-effective over another of face-to-face physiotherapy three times a week in the same length of time for individuals aged ≥65 following primary Total Knee Arthroplasty (TKA)?

Methods

Design

It was a single-centre study. A consecutive sampling was used with participants pre-randomized into two groups in a classical experimental design with assessment before and after the intervention[20]. For the sample size calculation, the 2021 Census reported there were 2,424,122 people aged 65 or older[1]. In the same year, 1,448 primary total knee arthroplasties (TKA) were performed according to the Registo Português de Artroplastias, resulting in a proportion of approximately 0.000597[21]. Using the formula $n=[(Z^2 \times p \times (1 - p)) / d^2]$ for a 1% margin of error and a 95% confidence interval, where (Z=1.96), the minimum sample size needed is 23 individuals.

Group 1 served as the experimental group, while Group 2 functioned as the control group and served as the comparator. The economic evaluation used CEA methods by calculating the ICER for comparison[18]. Although not sequentially and as far as applicable, the study aimed to comply with as many items as possible in the Consolidated Health Economic Evaluation Reporting Standards statement (CHEERS)[22].

Participants, therapists, centres

Eligible participants included all individuals aged 65 years or over who underwent primary TKA and began outpatient physiotherapy at the hospital where the study was conducted. Additionally, among these individuals, those who accepted the invitation met the inclusion and exclusion criteria listed in Table 1. To reduce the risk of bias, since the study was not blinded, the physiotherapy treatments were provided by independent physiotherapists of the hospital who did not have access to the study details, including the group to which each participant belonged.

Table 1. Inclusion and exclusion criteria

Inclusion criteria
To be referred for outpatient physiotherapy at the hospital of the study
To accept the invitation
Exclusion criteria
Before the beginning of the study
Postoperative complications
Hearing, visual, or other impairment that prevent from carrying out the home exercise program
Recent injury or orthopaedic surgery on the lower limbs (≤1 year)
To be undergoing active or maintenance cancer therapy
In the initial assessment

	Unable to understand the home exercises or to reproduce them [a)]
During the study	
	Physiotherapy plan abandonment
	Missing ≥3 physiotherapy sessions
	Less than 50% home exercises performed [a)]

Legend: [a)] Applied only to Group 1.

The study was conducted from September 27 to December 31, 2022, at the physiotherapy department of a tertiary hospital in Lisbon.

Intervention

The baseline assessment was conducted before the first physiotherapy session, and the endline assessment was performed in the last session of the 5th week for both groups. Before the first physiotherapy session, individuals who agreed to participate in the study were informed about the purpose, procedures, and nature of their participation. They were also made aware that they were free to withdraw from the study at any time. Then they signed the informed consent form. After that, they completed the demographic questionnaire, and the baseline assessment was conducted by filling out the OKS questionnaire, measuring the AROM of the operated knee, and accomplishing the 30s Chair Stand Test. Following this initial assessment, participants randomized to Group 1 were taught the home exercises and were asked to reproduce them correctly. These home exercises were designed to improve mobility, muscle strength, and proprioception on both stable and unstable surfaces. Three examples of these exercises can be seen in Figure 1. Those who were unable to replicate the exercises would be excluded from the study. They were also given a leaflet illustrating the exercises, as well as a recording form to log their completion. This form was collected weekly until the endline assessment.

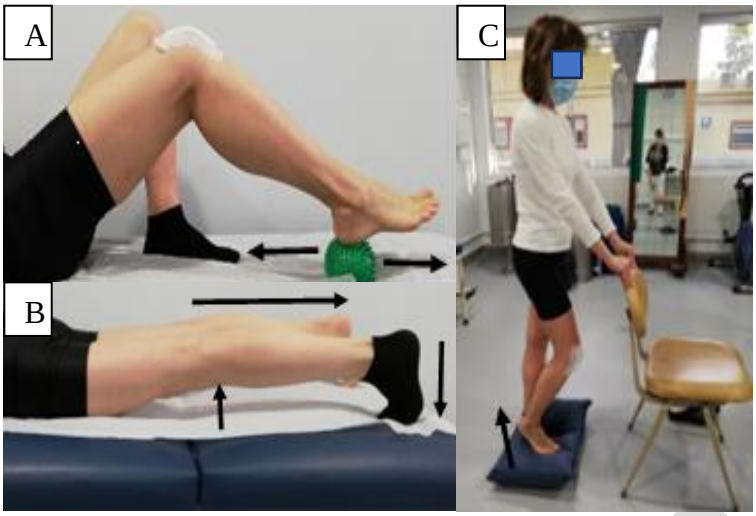


Figure 1. Examples of home exercises to improve mobility (A), muscle strength (B), and proprioception (C).

The participants of Group 1 received a two-weekly session of face-to-face physiotherapy complemented with home exercises twice a day. On treatment days, these exercises were performed only once. This plan served as the alternative. The participants of Group 2 received face-to-face physiotherapy three times a week as the usual rehabilitation plan. The plan of Group 2 served as the comparator.

The flowchart illustrating the study process from post-TKA surgery to the endline assessment in the final session is presented in Figure 2.

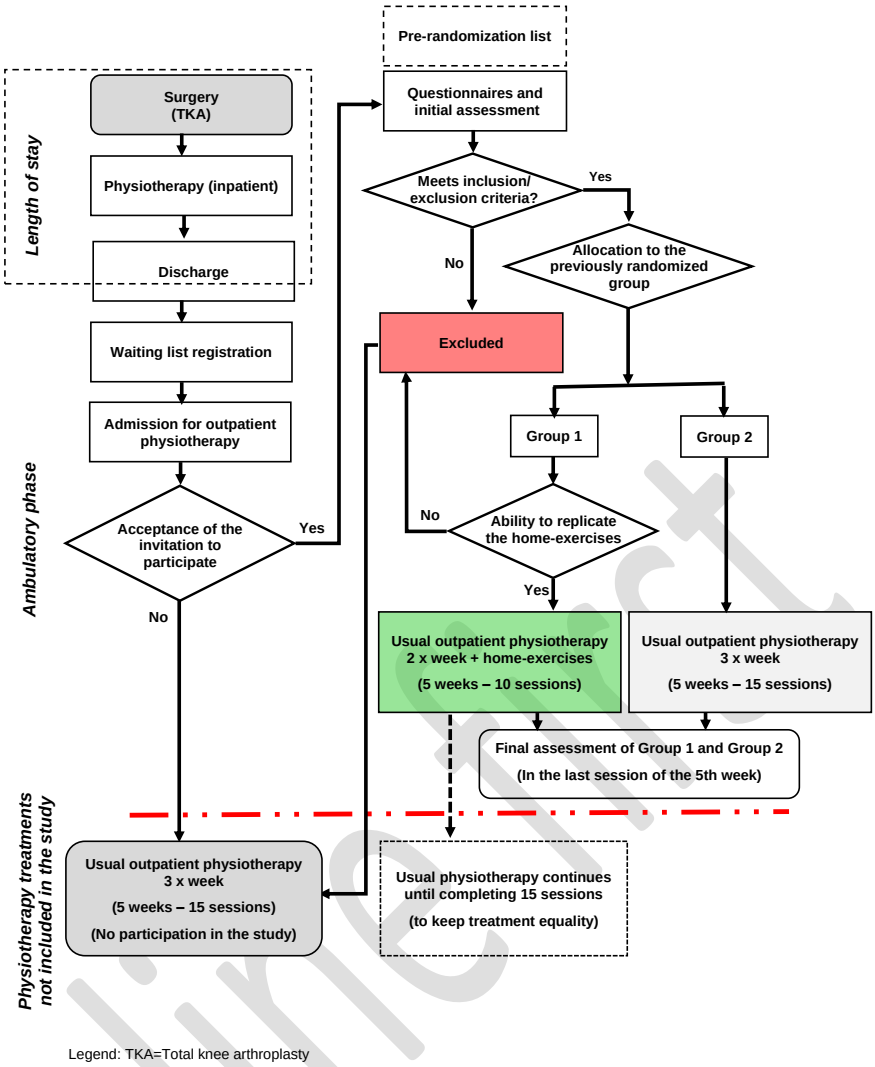


Figure 2. Flowchart of the study process.

Outcome measures

Effectiveness outcome: The effectiveness was assessed by measuring its subcomponents separately, which constituted its variables. The effectiveness subcomponent variables were as follows: pain, function, knee joint AROM in flexion, knee joint AROM in extension, and lower limb muscle strength. The measuring instrument used to assess pain and function was the Oxford Knee Score (OKS), specifically the version validated for the Portuguese population. The scale ranges from 12 to 60 points, with 12 points indicating the best condition and 60 points indicating the worst[23]. To assess each of these subcomponents of effectiveness, the set of pain items and function items was measured separately. AROM, both in flexion and extension, was measured using a universal goniometer. To measure AROM in flexion, the participant was positioned in the prone position, while for extension, the participant was positioned in the supine position[24]. To assess lower limb muscle strength, the 30s Chair Stand Test (30s-CST) was

used[25-26]. During this test, from a sitting position in a chair without arms for support and with a height between 43 and 46 centimetres, the number of times the participant stood up and sat down within 30 seconds was counted. The calculated values for the various subcomponents of effectiveness were derived from the differences between the means of the measured values at the baseline and endline assessments.

Cost calculation: The cost of physiotherapy treatments was calculated from the institutional perspective, considering only direct costs. The cost valuation was calculated in euros using the price list for Complementary Diagnostic and Therapeutic Means (MCDT)[27]. In the study, it was assumed that the cost of each physiotherapy session was the same for all participants. Based on this assumption, the cost of each rehabilitation plan was calculated using the following formula:

$$C = \frac{\sum_{i=1}^{24} c_i}{24} \text{ X } G$$

where *C* represents the cost of rehabilitation plan per participant for the group in question; *c* is the real cost of one physiotherapy session for each participant (this real cost varied among participants); *G* indicates the number of physiotherapy sessions carried out by each participant according to the respective randomized group (i.e., in Group 1 *G*=10, in Group 2 *G*=15).

In the CEA, a comparative assessment is conducted on the ratios between the costs associated with physiotherapy procedures and the resulting health outcomes[18]. Using this methodology, the two groups were compared by calculating the ICER for each subcomponent of effectiveness with the following formula:

$$ICER = \frac{C_1 - \text{C}_2}{E_{1-}E_2}$$

where C_1 and E_1 are, respectively, the cost and effectiveness subcomponent of Group1 and C_2 and E_2 are the cost and effectiveness subcomponent of Group 2.

The overall ICER was obtained by averaging all the subcomponent ICERs, since the different variables were measured in different units. In the study, it was assumed that the various effectiveness subcomponents had equal weight on health outcomes.

Data analysis

The instruments used for data collection were as follows: a demographic questionnaire designed specifically for sociodemographic data and clinical information; a table for recording the cost of each physiotherapy procedure, valued according to the correspondent code in MCDT

price list; the OKS questionnaire; a table for recording goniometry measurements of knee AROM in flexion and extension; and a table for recording the scores from 30s Chair Stand Test.

Considering a 95% confidence interval (CI) and a significance level of 5%, a statistical comparison of the two groups was conducted using parametric and non-parametric tests, depending on whether the data showed a normal distribution[28-29]. This analysis was performed for independent samples at both the baseline and endline assessments. To compare the changes within each group, between the baseline and the endline assessments, both parametric and non-parametric tests for paired samples were employed. The statistical analyses were conducted using commercial software IBM SPSS v. 27.0 and MS Excel 2016.

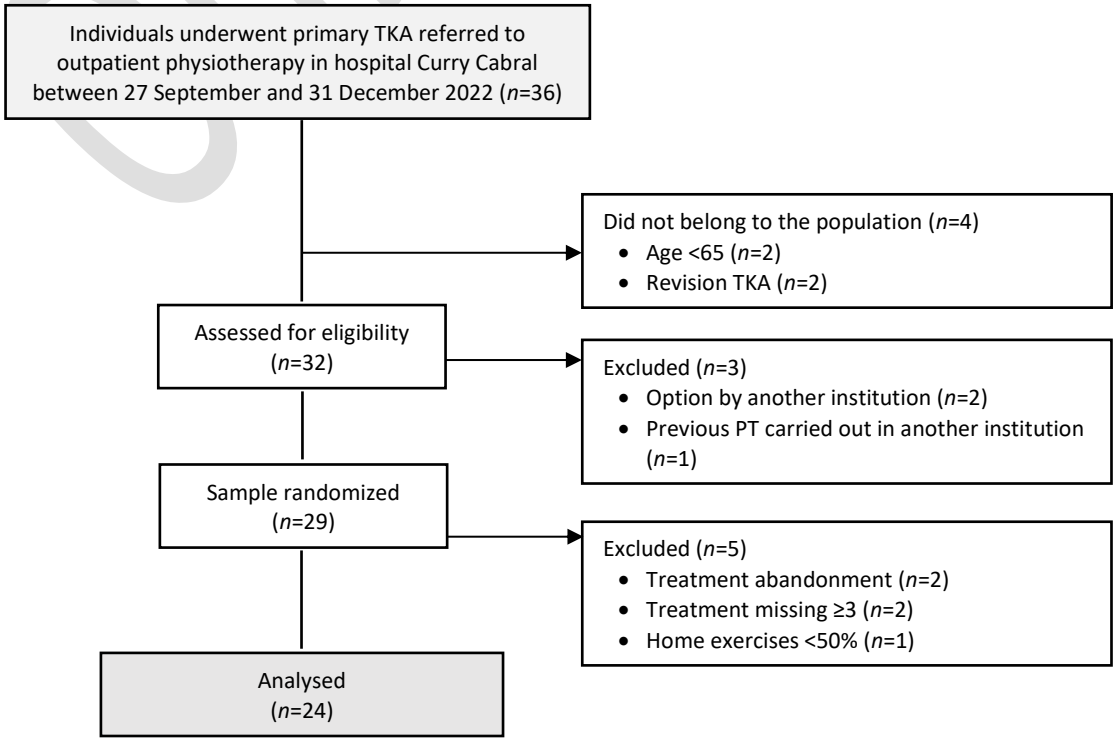
Ethical approval

The Ethics Committee for Health of Centro Hospitalar Universitário de Lisboa Central (Process no. 1263/2022) and the Ethics Committee of Escola Superior de Tecnologia da Saúde de Lisboa (CE-ESTeSL no. 66/2022) approved this study. All participants gave written informed consent before data collection began.

Results

Flow and characteristics of participants

A total of 36 individuals underwent TKA in the hospital within the study time horizon. The final sample consisted of 24 individuals. Figure 3 illustrates the flow of participants and the reasons for exclusions.



Legend: TKA = Total knee arthroplasty; PT = Physiotherapy.

Figure 3. Flow of participants.

Most participants were female (75%), and nearly all had a low level of education. The average age was approximately 73 years, as shown in Table 2.

Table 2. Demographic characteristics of participants

Characteristic	Group 1 (*n*=15)	Group 2 (*n*=9)	All participants (*n*=24)
Gender, *n* (%)			
Male	2 (13)	4 (44)	6 (25)
Female	13 (87)	5 (56)	18 (75)
Age (y), mean (SD)	74 (3.3)	70 (3.8)	73 (3.9)
Education level, *n* (%) [a)]			
None	1 (7)	-	1 (4)
Level 1	11 (73)	7 (78)	18 (75)
Level 2	2 (13)	1 (11)	3 (13)
Level 5 or upper	1 (7)	1 (11)	2 (8)

Legend: [a)] According with ISCED-11, International Standard Classification of Education.

Effectiveness outcome

At baseline, both groups showed similar values in effectiveness subcomponents, as presented in Table 3. This is supported by the statistical tests for comparing means, which indicated no statistically significant differences between the two groups (see Table 4).

In Group 1, the comparison of means between baseline and endline assessments shows improvements in all effectiveness variables, with an overall average of 88%. These observed changes correspond to health gains. In Group 2, there were also improvements in all variables, with an overall average of 44%. However, all of these improvements were smaller than those in Group 1. These comparisons are also presented in Table 3. To provide a clearer perspective on the comparison of health gains, a graphic representation is illustrated in Figure 4. In both groups, all changes were statistically significant except for AROM extension in Group 2 (see Table 4).

Table 3. Pairwise comparisons (95% CI)

Outcome	Baseline		Endline		Health gain			
	Group 1 (*n*=15)	Group 2 (*n*=9)	Group 1 (*n*=15)	Group 2 (*n*=9)	Group 1 (*n*=15)		Group 2 (*n*=9)	
	Mean (SD)		Mean (SD)		Mean (SD)	%	Mean (SD)	%
Pain [a)] (7 to 35 points)	21.1 (5.1)	19.6 (5.1)	13.2 (3.1)	13.9 (4.0)	7.9 (4.7)	37	5.7 (4.8)	29
Function [a)] (5 to 25 points)	16.6 (3.3)	15.8 (3.1)	12.2 (1.8)	12.9 (3.3)	4.4 (3.6)	27	2.9 (2.2)	18
AROM flex (deg)	54.0 (12.9)	51.7 (17.7)	81.0 (9.5)	72.2 (15.8)	27.0 (11.9)	50	20.6 (13.3)	40
AROM ext	-8.3	-10.6	-3.0	-8.9	5.3	64	1.7	16

(deg)	(7.2)	(8.8)	(4.9)	(7.0)	(5.8)		(4.3)	
Muscle strength (number of stands)	2.7 (2.9)	4.1 (4.0)	9.7 (1.6)	9.0 (3.4)	7.0 (2.8)	263	4.9 (4.1)	119
Average of overall health gain (%)						88		44

Legend: AROM = Active range of motion; flex = flexion; ext = extension.
[a)] In the version of OKS used (12 to 60), lower values indicate a better condition; therefore, to achieve health gain values the difference in outcomes from baseline to endline was multiplied by -1.

Table 4. Statistical tests for comparisons (95% CI)

	Between groups				Within each group (baseline-endline)				Between groups	
	Baseline		Endline		Group 1 (*n*=15)		Group 2 (*n*=9)		Health gain	
	t (*p*)		*t* (*p*)		*t* *p*		*t* *p*		*t* *p*	
Pain	.70. (.49)	a)	-.47 (.64)	a)	6.5 (<.001)	a)	3.5 (.008)	a)	1.1 (.28)	a)
Function	.61 (.55)	a)	.03 (.98)	b)	4.7 (<.001)	a)	-2.5 (.01)	c)	1.1 (.27)	a)
AROM flexion	.37 (.71)	a)	-1.34 (.19)	b)	3.4 (<.001)	c)	-4.6 (.002)	a)	1.2 (.23)	a)
AROM extension	.67 (.51)	a)	-2.1 (.06)	b)	2.7 (.008)	c)	1.1 (.26)	c)	1.6 (.12)	a)
Muscle strength	1.1 (.32)	b)	.66 (.52)	a)	3.4 (<.001)	c)	-3.5 (.008)	a)	-1.9 (.06)	b)

Legend: AROM – Active range of motion; *t*=*t*-test; *p*=*p*-value.
a) Parametric test (*t*-test).
b) Non-parametric test (Mann-Whitney U test).
c) Non-parametric test (Wilcoxon signed rank test).

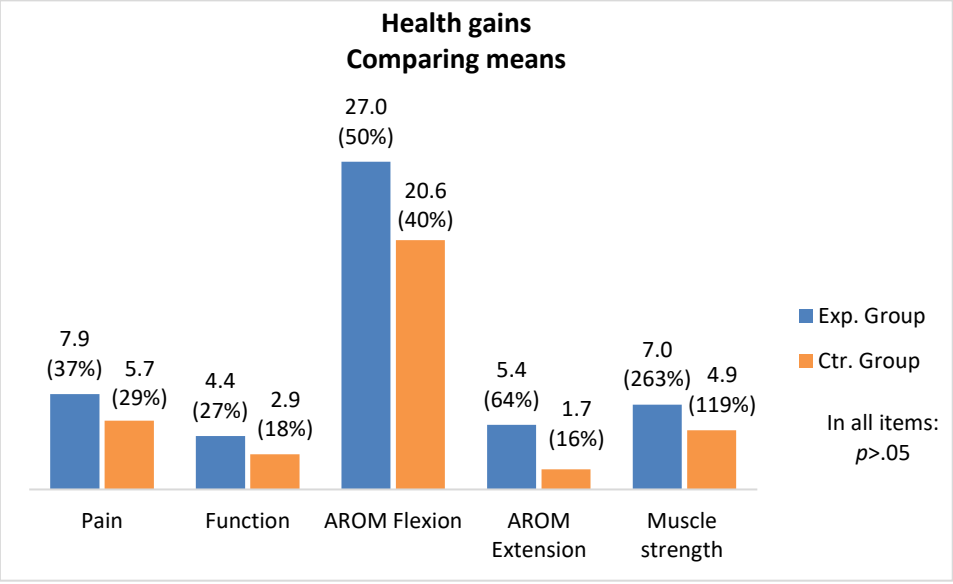


Figure 4. Health gains graphic.

As was done for the baseline assessment, a comparison between the groups was conducted during the endline assessment. The results of the comparisons presented in Table 4 reveal that at the final assessment, there were no statistically significant differences in all effectiveness indicators analysed between Group 1 and Group 2.

Cost calculation

Physical therapy procedures are generally similar across individuals. However, the variability observed in the MCDT amounts arises from the individual coding choices made by referring professionals. For instance, for the same treatment, a professional may select among several possible codes, depending on their interpretation or preference, such as:

- 61102 – Manual muscle strengthening
- 60290 – Manual joint mobilization
- 61104 – Muscle strengthening/ joint mobilization
- 60377 – Special kinesiotherapy techniques

Hence, as these differences did not reflect the true cost, the study used the average value for its calculations. This average was derived from all procedures across all participants, rather than on a group-by-group basis, to provide a more representative cost estimate and facilitate more meaningful comparisons.

The cost calculation commenced with determining the average session cost per participant, as detailed in Table 5, which was € 19.11. Group 1 underwent 10 treatment sessions, resulting in an average treatment cost of € 191.13 per participant. Group 2 received 15 sessions, leading to a higher average cost of € 286.69. The cost difference was solely due to the number of sessions – since the per-session cost was identical, the total cost for Group 2 was 1.5 times that of Group 1.

Table 5. Valuation and calculation of the costs for physiotherapy procedures performed based on MCDT price list

MCDT price list code	PT procedure unit price (€)	Group 1 (*n*=15	Group 2 (*n*=9)	All participants (*n*=24)
		PT procedures performed Cost of procedures (€)		
60222	5.10	3 15.30	2 10.20	5 25.50
60233	8.50	1 8.50	- -	1 8.50
61102	4.80	7 33.60	5 24.00	12 57.60
60290	4.90	7 34.30	5 24.50	12 58.80
60377	7.20	9 64.80	8 57.60	17 122.40

60404	6.10	14	9	23
		85.40	54.90	140.30
61104	3.80	8	4	12
		30.40	15.20	45.60
Overall cost of PT procedures per session (€)				458.70
Average session cost per participant (€)				19.11(3…)
Cost of the Group 1 plan per participant (€) [a)]				191.13
Cost of the Group 2 plan per participant (€) [b)]				286.69

Legend: MCDT = Complementary diagnostic and therapeutic means; PT = Physiotherapy.
[a)] Group1 plan consisted of 10 sessions.
[b)] Group 2 plan consisted of 15 sessions.

Based on the results of the costs and effectiveness achieved, the ICER calculation is presented in Table 6, showing an ICER of € -38.82.

Table 6. ICER calculation

Effectiveness subcomponent (Outcome)	$\frac{C_1 - C_2}{E_1 - E_2}$	ICER
Pain	$\frac{191.13 - 286.69}{7.9 - 5.7}$	- 43.44
Function	$\frac{191.13 - 286.69}{4.4 - 2.9}$	- 63.71
AROM flexion	$\frac{191.13 - 286.69}{27.0 - 20.6}$	- 14.93
AROM extension	$\frac{191.13 - 286.69}{5.3 - 1.7}$	- 26.54
Muscle strength	$\frac{191.13 - 286.69}{7.0 - 4.9}$	- 45.50
Overall effectiveness ICER		**- 38.82**

Legend: ICER = Incremental cost-effectiveness ratio; AROM = Active range of motion; flex = flexion; ext = extension.

In a graphical representation on the incremental cost-effectiveness plane, this result falls in the south-east (SE) quadrant, indicating that the new intervention is more effective and less costly than the comparator (see Figure 5).

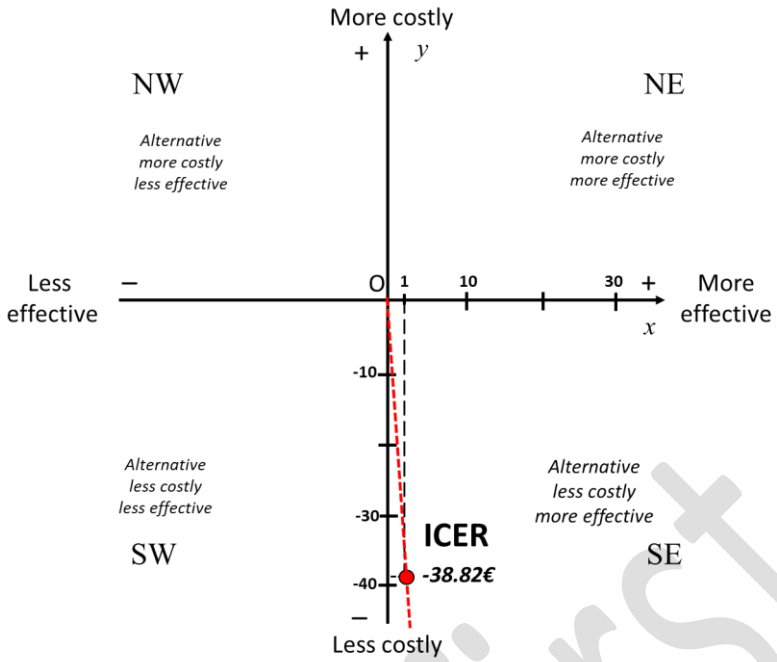


Figure 5. Cost-effectiveness plane.

Discussion

The design and approach of this study required more involvement from individuals undergoing TKA, giving them greater responsibility and relevance in their rehabilitation process. This involvement made them partners with the physiotherapist. In the study, both groups showed improvements in all effectiveness indicators, with the majority demonstrating statistically significant differences between baseline and endline assessments. The comparison between the two groups indicated that the plan of Group 1 was dominant, demonstrating that it is possible to achieve better clinical outcomes at a lower cost, despite not finding significant differences between the two groups, in rehabilitation following primary TKA.

The main strengths of the study were the overall design, which allows for replications by future researchers, and the random assignment of participants to each group.

The study had some limitations. First, the sample size was small, which decreased the accuracy of statistically assessing potential differences between the two treatment plans. Furthermore, since the sample was consecutive, the findings cannot be generalized to the entire population of individuals undergoing TKA. Additionally, the short timeframe in which it occurred, especially when using the OKS questionnaire as the measuring instrument, limited the results obtained since the OKS was designed to compare assessments over a longer period. Finally, the fact that only direct costs have been considered in the economic analysis was also a limitation.

Despite the limitations mentioned, the results are still interesting. Therefore, it is recommended to implement a plan identical to that of Group 1 in this study. It is also

recommended that future studies be conducted over a period of at least one year, with a significantly larger sample size, preferably using a probabilistic approach. Additionally, a preoperative assessment of the measurement variables, which were used to evaluate effectiveness in this study, should be considered. Furthermore, it is worth considering assessments by more than one evaluator and the impact of surgery on the contralateral knee.

Conclusions

What was already known on this topic: Healthcare systems are facing upward financial pressures worldwide. TKA is one of the most common surgeries. This also contributes to increasing the healthcare burden. Physiotherapy is widely recommended after TKA, and starting it as early as possible optimizes outcomes in both the short and medium term.

What this study adds: Despite the limitations faced by the study, the results are encouraging. The study demonstrates that a rehabilitation plan involving face-to-face physiotherapy twice a week, complemented by home-based exercises, achieves better outcomes while using fewer resources than a plan with face-to-face physiotherapy three times a week. Therefore, the first approach is more advantageous for hospitals and for individuals undergoing TKA.

Authors contribution. AG carried out the conception and design of the study, participant selection, data collection, analysis, and interpretation, and drafted the manuscript; ME carried out the final critical review of the manuscript; AC collaborated in the conception and design of the study and in the critical review of the manuscript; GC collaborated in data analysis.

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Conflito de interesses

Os autores declaram não possuir quaisquer conflitos de interesse.

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