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Original Research

Lower limbs amputation and physiotherapy rehabilitation at the National Authority for Prosthetics and Orthotics, Sudan

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ABSTRACT

Background: Each year, approximately 150,000 individuals in the United States undergo lower extremity amputations. In Sudan, a range of rehabilitation services for amputation patients is offered through organizations in both governmental and public sectors. The National Authority for Prosthetics and Orthotics (NAPO) adopts a multidisciplinary rehabilitation approach to help amputation patients achieve independence in their daily lives.

Objective: The aim of this study was to explore the knowledge and experience of lower limb amputees regarding physiotherapy rehabilitation at the NAPO institution.

Method: The study employed a descriptive cross-sectional design involving 81 participants at NAPO. Data collection was carried out using a questionnaire comprising 29 questions. Data analysis was conducted using Microsoft Excel. All ethical considerations were thoroughly upheld.

Results: A total of 74.1% of participants had diabetes mellitus, which was the main cause of amputation. Transtibial amputation was performed in 65.4% of the study population. For 44.4% of participants, the rehabilitation program started 6–12 months after surgery. A total of 88.9% of respondents did not perform any form of exercise before amputation surgery. Additionally, 65.4% of participants did not perform any self-management of their lower limb amputation scar at home. A total of 59.3% of participants perceived physiotherapy rehabilitation at NAPO as more effective than physiotherapy rehabilitation at home.

Conclusion: The multidisciplinary rehabilitation program implemented at NAPO for lower limb amputees has proven to be highly effective. However, greater emphasis should be placed on pre-amputation rehabilitation, delayed post-amputation physiotherapy rehabilitation, addressing patients' psychological well-being, and providing education on home care and exercise routines.

1. Introduction

Amputation is a transformative procedure frequently performed when tissue cannot be preserved, designed to eliminate diseased tissue and enhance mobility or overall quality of life. It involves the surgical removal of a body part, often necessitated by complications arising

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from medical conditions such as severe injuries, infections, cancer, or diseases like peripheral artery disease. In the United States, around 12% of emergency department visits by patients result in amputations (Yuan *et al.,* 2023). In Africa, numerous amputation surgeries are performed to prevent complications arising from diabetes, particularly in countries with high rates of diabetic patients, such as Sudan (Hassan *et al.,* 2023). During World War I, approximately 41,000 British and 67,000 German individuals required amputations. In contrast, amputations resulting from the Russian-Ukrainian war in 2023 ranged between 20,000 and 50,000 (Porter, 2023).

The lower limbs are the most commonly amputated parts of the body (Abdelnour *et al.,* 2025). Approximately 150,000 patients per year undergo a lower extremity amputation in the United States (Molina & Faulk, 2025). Lower limb amputation is associated with postoperative mortality rates ranging from 7% to 23% and morbidity rates between 15% and 40% (Qaarie, 2023). More than half of all lower limb amputation cases are attributed to peripheral artery disease in conjunction with diabetes mellitus (Adams & Lakra, 2023). Additional causes encompass trauma, severe infections, burns, frostbite, and tumors.

Physiotherapy is a healthcare profession dedicated to maintaining optimal functional abilities in the presence of various conditions that may affect body systems (Alkazaleh *et al.,* 2025). Its primary focus is on restoring and improving movement to promote functional independence and enhance overall quality of life (Adam *et al.,* 2025). Among the limited number of physiotherapists in Sudan, they are making significant efforts in rehabilitation programs within the Sudanese community (Abdalrhman *et al.,* 2025). These efforts encompass the rehabilitation process for individuals who have undergone amputations. Additionally, various institutions within governmental and public sectors provide rehabilitation services to support amputation patients (Abdelnour *et al.,* 2025).

Rehabilitation is a customized, multifaceted healthcare approach aimed at restoring, maintaining, or enhancing physical, mental, and cognitive abilities that may have been compromised by injury, illness, or medical treatment (WHO, 2024). Its goal is to promote independence, minimize disabilities, and improve daily functionality through methods such as therapy, education, and the use of assistive tools. Recently, the medical education system in Sudan has concentrated on enhancing rehabilitation care and adopting a multidisciplinary approach. Physiotherapy is one of the health professions engaged in rehabilitation. However,

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the rehabilitation process encounters multiple challenges, which result in limitations in both service quality and accessibility.

The National Authority for Prosthetics and Orthotics (NAPO), Sudan, was founded in 1964. In partnership with the International Committee of the Red Cross (ICRC), NAPO offers prosthetic limbs, orthotic devices, and rehabilitation services to support individuals with physical disabilities (Bushra *et al.,* 2023). In other words, NAPO adopts a multidisciplinary rehabilitation team approach to help amputation patients achieve independence in their daily lives. It serves as the leading healthcare institution in Sudan, specializing in providing rehabilitation services for patients with amputations. The primary center is situated in Khartoum, with additional branches spread across various regions of the country.

Sudan, situated in East North Africa, is regarded as one of the developing nations (Napelion *et al.,* 2025). Sudan shares its borders with Egypt, Libya, Chad, Eritrea, Ethiopia, South Sudan, and the Central African Republic. Sudan has been experiencing a civil war leading to low standards of health infrastructure and resources (Satti *et al.,* 2025). The majority of amputation cases in Sudan result from complications associated with diabetic foot (Ahmed *et al.,* 2021). The aim of this study is to investigate the knowledge and experience of lower limb amputees regarding physiotherapy rehabilitation at NAPO in Sudan.

2. Method

Research design

This study employed a quantitative descriptive approach with a cross-sectional design to describe the knowledge and experience of lower limb amputees regarding physiotherapy rehabilitation. This design was selected as it allows researchers to collect data from participants at a single point in time efficiently and representatively. The study was conducted at the NAPO in Khartoum, Sudan, which serves as the primary referral center for amputation rehabilitation in the country.

Participants

The study population consisted of all lower-limb amputees who visited NAPO between May and August 2024. Participants included individuals aged 30 years and above, while those with upper-limb amputations, visual impairments, or hearing deficits were excluded. A total of 81 participants were enrolled in the study.

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To ensure the study was representative of the population at the NAPO institution, the sample size was calculated using the following steps: 1) The initial sample size (n_o) was determined using Cochran's formula for an infinite population, assuming a 95% confidence level (Z = 1.96), a 5% margin of error (e), and a population proportion (p) of 50% to ensure maximum variability:

$$n_0 = \frac{(Z)^2 \times p \times (1-p)}{(e)^2} \quad (1)$$

$$n_0 = \frac{(1.96)^2 \times 0.5 \times (1-0.5)}{(0.05)^2} = 384.16$$

2) Since the initial sample size (n_o = 384.16) was larger than the actual target population of visitors at NAPO (N = 100), the finite population correction was applied using the formula:

$$n = \frac{n_0}{1+\frac{n_0-1}{100}} \quad (2)$$

$$n = \frac{384.16}{1+\frac{384.16-1}{100}} = \frac{384.16}{1+\frac{383.16}{100}} = \frac{384.16}{1+3.8316} = \frac{384.16}{4.8316} = 79.51$$

The calculation determined that a minimum of 80 participants was required for statistical validity. The study successfully enrolled 81 participants, thereby meeting the required threshold for a representative sample of the lower-limb amputee population at NAPO during the study period.

Data collection

Data collection was carried out using a closed-ended questionnaire comprising 29 questions, which was developed by the researchers based on the study objectives. The questionnaire was divided into four sections: personal demographic information, details regarding the patient's lower limb amputation condition, knowledge about lower limb amputation, and experience related to lower limb amputation.

A pilot study was conducted involving 10 lower limb amputees at NAPO; these individuals were not included in the final study sample. The sections on Knowledge and Experience showed high reliability, indicating that the items effectively measured the intended constructs. The average time to complete the 29 questions was 10 to 15 minutes. This was deemed acceptable for the target population.

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Data analysis

All data collected through the questionnaire were manually entered into a Microsoft Excel worksheet for tabulation and verification. Descriptive statistical analysis was performed to calculate the frequencies and percentages of each variable under investigation, including demographic characteristics, clinical conditions, knowledge, and experiences of participants. The analysis results were then presented in frequency distribution tables and charts to facilitate systematic interpretation and data presentation.

Ethical considerations

Approval to conduct this study was granted by the Ethical Committee of Ahfad University for Women (AUW) (Ethics Reference Number: SHS 22/5/44). Permission was also secured from the NAPO institution to engage with and work alongside lower limb amputees at their facility. Additionally, written informed consent was obtained from all participants**.**

3. Results

Descriptive data analysis was conducted to characterize the demographic profile, clinical conditions, knowledge level, and experiences of participants regarding physiotherapy rehabilitation. Overall, the findings revealed that the majority of participants were male, aged between 51 and 60 years, and resided in Omdurman and other Sudanese states. Diabetes mellitus was identified as the primary cause of amputation, with transtibial amputation being the most common level. Most participants initiated physiotherapy rehabilitation within 6–12 months post-surgery, and only a small proportion engaged in pre-operative exercises. NAPO served as the main source of information about physiotherapy, and the majority of participants perceived physiotherapy rehabilitation at NAPO to be more effective than home-based rehabilitation. The detailed findings are presented below.

Demographic of participants

Table 1 presents the demographic characteristics of the participants. Males accounted for 75.3% of participants, while females comprised 24.7%. Regarding age distribution, the 51–60 years age group was the largest (38.3%), followed by those aged over 60 years (27.2%). Only 16.0% of participants were aged 30–40 years. In terms of place of residence, 38.3% of participants resided in Omdurman, while 34.6% came from other states of Sudan. A total of 13.6% lived in Khartoum and 13.6% in Khartoum Bahri. Concerning marital status, the majority were married (87.7%), while 8.6% were divorced and only 3.7% were single. No

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widowed participants were identified in this study.

Table 1. Demographic characteristics of participants (n=81)

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	61	75.3
	Female	20	24.7
Age (years)	30–40	13	16.0
	41–50	15	18.5
	51–60	31	38.3
	>60	22	27.2
Residence	Khartoum	11	13.6
	Khartoum Bahri	11	13.6
	Omdurman	31	38.3
	Other States	28	34.6
Marital Status	Single	3	3.7
	Married	71	87.7
	Divorced	7	8.6
	Widowed	0	0.0

Figure 1 illustrates the prevalence of comorbid diseases among participants. Diabetes mellitus was present in 74.1% of participants, while only 1.2% had hypertension, and the remaining participants had no comorbid diseases. The high prevalence of diabetes mellitus confirms that diabetes is a major risk factor contributing to the high rate of lower limb amputations in Sudan. This finding is consistent with previous reports indicating that diabetic foot complications are the primary cause of amputation in developing countries.

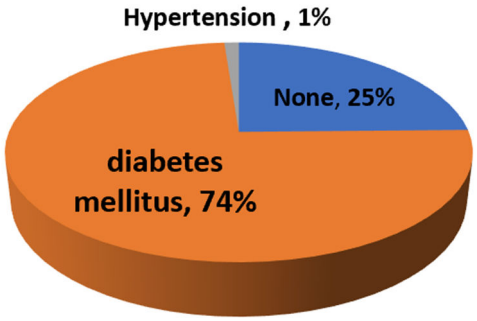

Figure 1. Distribution of comorbid diseases among participants

Table 2 presents the primary causes of lower limb amputation as reported by participants. Diabetes mellitus was the leading cause, accounting for 66.7%, followed by accidents at 17.3%, mycetoma at 9.9%, and vascular problems at 6.2%. These data reinforce previous findings that diabetes mellitus is not only the dominant comorbid condition but also the direct primary cause of amputation. Accidents and mycetoma also contributed

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significantly, reflecting the high risk of trauma and fungal infections in the Sudan region.

Table 2. Causes of lower limb amputation (n=81)

Cause	Frequency (n)	Percentage (%)
Diabetes Mellitus	54	66.7
Accident	14	17.3
Mycetoma	8	9.9
Vascular Problem	5	6.2

Figure 2 depicts the level of lower limb amputation among participants. The majority of participants (65.4%) underwent amputation at the transtibial level (below the knee), followed by transfemoral amputation at 27.2% and knee disarticulation at 7.4%. The predominance of transtibial amputation indicates that preserving the knee joint is a priority in surgical amputation practice in Sudan. More distal amputation levels are generally associated with better functional prognosis and easier prosthetic fitting.

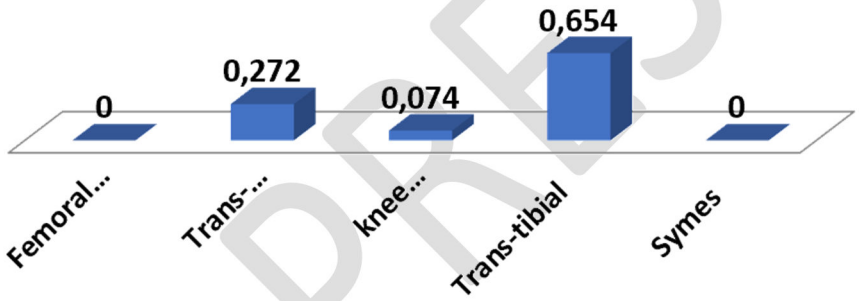

Figure 2. Level of lower limb amputation

Table 3 shows the time interval between amputation surgery and the initiation of the rehabilitation program. Among participants, 44.4% started rehabilitation within 6–12 months post-surgery, followed by 32.1% who started within 3–6 months. A total of 12.3% initiated rehabilitation more than one year post-surgery, and 11.1% initiated it more than two years post-surgery. This delay indicates a significant gap in access to post-amputation rehabilitation services in Sudan. Early initiation of rehabilitation is crucial for preventing complications such as joint contractures, muscle atrophy, and delayed prosthetic fitting.

Table 3. Time Interval between amputation surgery and initiation of rehabilitation (n=81)

Time Interval	Frequency (n)	Percentage (%)
3–6 months	26	32.1
6–12 months	36	44.4
>1 year	10	12.3
>2 years	9	11.1

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Knowledge about physiotherapy

Figure 3 illustrates participants' knowledge about physiotherapy prior to amputation. A total of 68.0% of participants had heard about physiotherapy before the amputation surgery, while 32.0% had not. This figure indicates that most patients had some initial awareness of the importance of physiotherapy, although not necessarily having undergone it. However, approximately one-third of patients had no prior knowledge about physiotherapy before undergoing amputation.

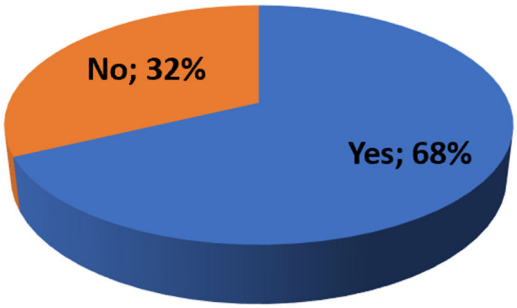

Figure 3. Knowledge about physiotherapy before amputation

Table 4 presents the sources of knowledge about physiotherapy among participants who were previously aware (n=55). The majority (56.4%) obtained information from NAPO, followed by hospitals (16.4%), family (10.9%), media (9.1%), friends (5.4%), and university (1.8%). The dominance of NAPO as a source of information highlights the central role of this institution in educating amputation patients in Sudan. The involvement of family and media was also significant, indicating the need to strengthen community roles in disseminating information about physiotherapy rehabilitation.

Table 4. Sources of knowledge about physiotherapy (n=81)

Source of Knowledge	Frequency (n)	Percentage (%)
Family	6	10.9
Friends	3	5.4
Hospital	9	16.4
Media	5	9.1
NAPO	31	56.4
University	1	1.8

Experience of physiotherapy rehabilitation

Figure 4 shows participants' experience regarding pre-operative exercises before amputation surgery. The majority of participants (89%) did not perform any form of exercise

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before the amputation surgery, while only 11% underwent pre-operative exercises. This figure is concerning given that pre-operative exercises play an important role in preparing patients physically, preventing postoperative complications, and accelerating the rehabilitation process. The lack of access to information and pre-operative physiotherapy services is a major factor contributing to the low participation rate in pre-amputation exercises.

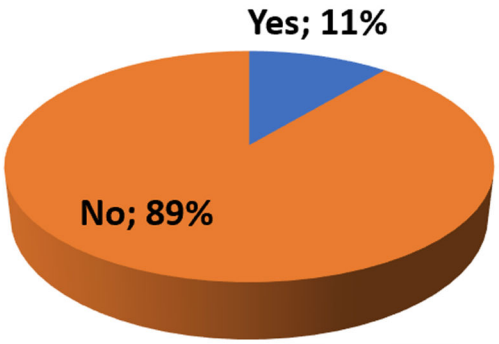

Figure 4. Experience of pre-operative exercises

Table 5 presents the self-management practices for lower limb amputation scars at home. A total of 65.4% of participants did not perform any form of scar management at home, while 34.6% applied massage as a form of self-management. No participants performed scar mobilization, even though scar mobilization is an essential component of rehabilitation to prevent adhesions and improve tissue flexibility. The low rate of self-management practices reflects the lack of education provided to patients regarding ongoing care at home.

Table 5. Self-management of amputation scar at home

Management Type	Frequency (n)	Percentage (%)
Massage	28	34.6
Mobilization	0	0.0
None	53	65.4

Figure 5 presents the comparison of physiotherapy rehabilitation effectiveness based on participants' perceptions. A total of 59% of participants perceived that physiotherapy rehabilitation at NAPO was more effective than home-based rehabilitation, while 41% perceived home-based rehabilitation as more effective. The majority of participants who favored NAPO reflects their confidence in the structured, multidisciplinary rehabilitation approach implemented at the institution. However, a considerable proportion of participants perceived home-based rehabilitation as more effective, which may be influenced by factors

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such as comfort, time flexibility, or limited transportation access to NAPO.

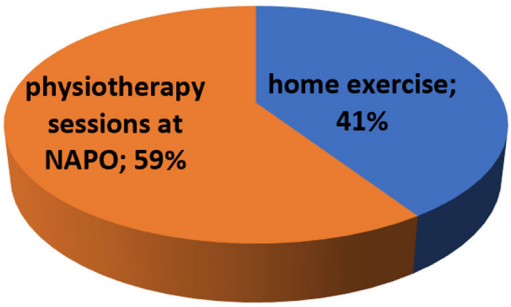

Figure 5. Physiotherapy rehabilitation effectiveness between NAPO and home

4. Discussions

Demographic characteristics and their implications for rehabilitation

The prevalence of lower limb amputation in this study was found to be three times higher in men compared to women. This finding is similar to the study conducted by Ahmad *et al.* (2024) in Greater Manchester, England, which found the overall occurrence of lower limb amputation was 3.8 times greater in men compared to women. This difference can be attributed to behavioral factors, such as higher exposure of men to heavy physical activities, occupational accident risks, and smoking habits that are more common among the male population in Sudan. Additionally, access to healthcare services, which may be more easily obtained by men than women within the local sociocultural context, also contributes to the higher proportion of male patients.

Research consistently highlights that the age group most commonly associated with lower limb amputations is typically between 60 and 79 years, with many studies pinpointing those over 70 years as the most affected (Koivunen *et al.,* 2024). However, in this study, the 51–60 age category emerged as the group with the highest incidence of lower limb amputations. This difference is likely due to specific demographic factors in Sudan, where lower life expectancy and the burden of metabolic diseases that manifest at younger ages may lead to complications requiring amputation earlier.

Most participants in this study resided in Omdurman and various other states of Sudan, with only a small proportion coming from Khartoum and Khartoum Bahri. This indicates that NAPO functions as a national rehabilitation center serving patients from various regions, including remote areas. The implication is that patients from outside Khartoum face additional challenges such as long travel distances and high transportation costs to access

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rehabilitation services regularly. These access limitations may be one of the contributing factors to delayed rehabilitation initiation and low adherence to long-term rehabilitation programs.

Causes and levels of amputation

Most participants with lower limb amputations in this study had diabetes mellitus, and complications associated with diabetes mellitus were also the primary cause of amputations observed. This finding aligns with Hassan *et al.* (2023), who identified diabetes mellitus and war-related injuries as the leading causes of amputations in Sudan. The prevalence of diabetes mellitus in Sudan is notably high, driven by factors such as rapid urbanization, increasingly sedentary lifestyles, and substantial dietary shifts, including greater consumption of refined carbohydrates and sugars (Awadalla *et al.,* 2017). This condition creates a double burden where the high prevalence of diabetes mellitus directly contributes to the high rate of amputations in the country.

The majority of study participants underwent amputation at the transtibial level. This agrees with the study conducted in Saudi Arabia by Alshehri *et al.* (2022), which found that transtibial, or below-knee amputation, is the most frequently performed lower limb amputation, constituting around 55% of cases. The selection of the transtibial amputation level is generally based on efforts to preserve the knee joint, which is crucial for maintaining functional mobility and facilitating prosthetic use. In the Sudanese context, the predominance of transtibial amputation also reflects the medical team's efforts to provide the best functional outcomes for patients, despite existing resource limitations.

Delayed initiation of rehabilitation

The majority of participants in this study began the physiotherapy rehabilitation program within 6 to 12 months following their lower limb amputation surgery. This period appears to be quite lengthy for initiating physiotherapy rehabilitation following lower limb amputation surgery, prosthetic fitting, and the post-prosthetic fitting phase. Delayed rehabilitation initiation has significant consequences for patient functional outcomes, including increased risk of joint contractures, muscle atrophy, phantom pain, and delayed adaptation to prosthetics.

There is insufficient literature addressing the specific reasons why individuals with lower limb amputations in Sudan begin physiotherapy with such significant delays. Existing studies

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primarily focus on accessibility challenges to physiotherapy rehabilitation as the main contributing factor (Abdelnour *et al.,* 2025). Other factors that may play a role include the lack of referrals from hospitals where surgery was performed, low awareness among patients and families about the importance of early rehabilitation, and the limited number of physiotherapists distributed across Sudan.

Knowledge and pre-operative practices

In this study, the majority of participants were already familiar with physiotherapy prior to undergoing lower limb amputation surgery. Most of them learned about it through NAPO, while a smaller number gained awareness from other sources, including hospitals, media, family members, and friends. NAPO's role as the primary source of information about physiotherapy demonstrates that this institution holds a strategic position in educating amputation patients in Sudan. However, on the other hand, the majority of participants in this study did not undergo pre-operative physiotherapy rehabilitation before amputation surgery. No clear justification for this was provided.

Pre-operative physiotherapy rehabilitation for lower limb amputation plays a vital role in minimizing complications such as contractures, infections, and phantom pain. This process focuses on preparing patients for improved mobility through targeted strengthening exercises, respiratory training, and comprehensive education for both patients and their caregivers (Knadmin, 2017). By addressing these areas, pre-operative rehabilitation enhances surgical outcomes and helps shorten recovery time. The lack of access to pre-operative physiotherapy services in Sudan represents a critical gap that requires serious attention from healthcare providers.

Self-management of scar at home

Patients frequently face challenges with self-managing lower limb amputation scars at home. This is often due to intense emotional distress, including feelings of grief, depression, and denial regarding their condition. Furthermore, physical limitations and a lack of proper education on scar management can also hinder their ability to care for themselves effectively (Aguado *et al.,* 2025; Zhu *et al.,* 2020). The majority of participants in this study did not engage in self-management of their lower limb amputation scars at home.

Proper self-care for lower limb amputation scars at home is crucial for encouraging faster healing, avoiding infections, and controlling swelling to ensure successful prosthetic fitting

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(Lee *et al.,* 2021). This involves routine practices such as cleaning the area, checking for any signs of skin issues, and utilizing compression shrinkers. These steps help alleviate pain, support long-term independence, and reduce the risk of complications such as falls or skin breakdown (Lee *et al.,* 2021). Neglecting self-care for lower limb amputation scars at home can result in complications such as skin breakdown, infections, painful scars, reduced mobility with prosthetics, and a heightened risk of falls.

Effectiveness of rehabilitation at NAPO

Structured and evidence-based physiotherapy rehabilitation programs, like those offered by NAPO, tend to be more effective for amputees compared to undertaking independent home exercises (Brown University Health, 2025; Gailey *et al.,* 2020). Most participants in this study found the physiotherapy rehabilitation program at NAPO to be more effective than performing it on their own at home. In essence, the physiotherapy rehabilitation program for lower limb amputation at NAPO substantially enhances functional independence, mobility, and quality of life. These positive outcomes are strongly linked to the effectiveness of the multidisciplinary care implemented at the institution.

The multidisciplinary approach at NAPO involves collaboration between physiotherapists, prosthetists, rehabilitation physicians, and other healthcare professionals in planning and implementing integrated rehabilitation programs. This approach enables comprehensive management, addressing not only physical aspects but also the psychological and social dimensions of patient care. The success of this approach is reflected in the high positive perception of participants regarding the effectiveness of rehabilitation at NAPO compared to home-based rehabilitation.

Study limitations

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design used can only capture a snapshot at a single point in time, thus unable to assess changes or developments in participants' knowledge and experience over time. Second, data collection using a questionnaire with closed-ended questions limited the depth of information obtained, particularly regarding the reasons behind certain findings such as rehabilitation delays or low self-management practices. Third, this study only involved participants from a single institution (NAPO), so generalization of findings to the overall lower limb amputation population in Sudan should be done with

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caution.

Implications for practice and future research

The findings of this study have several important implications for rehabilitation practice in Sudan. First, efforts are needed to improve access to pre-operative physiotherapy rehabilitation for patients undergoing amputation. Second, more intensive education needs to be provided to patients and families regarding the importance of early post-operative rehabilitation initiation and self-management of scars at home. Third, the multidisciplinary approach that has been successfully implemented at NAPO needs to be strengthened and expanded more broadly to other healthcare facilities in Sudan. Future research is recommended to use qualitative or mixed-methods designs to explore in greater depth the factors influencing rehabilitation delays and low self-management practices. Additionally, longitudinal studies are needed to evaluate the long-term functional outcomes of the rehabilitation program at NAPO.

5. Conclusion

The multidisciplinary rehabilitation program implemented at the NAPO for lower limb amputees has proven to be highly effective, as reflected in the positive perceptions of the majority of participants who rated NAPO rehabilitation as more effective than home-based rehabilitation. However, this study identified several critical areas requiring further attention, namely the low implementation of pre-operative rehabilitation, delayed initiation of post-amputation physiotherapy rehabilitation reaching 6–12 months in most patients, suboptimal management of patients' psychological well-being, and insufficient education regarding home care practices as evidenced by 65.4% of participants not performing scar management. Therefore, improving access to pre-operative rehabilitation services, strengthening referral systems to accelerate post-operative rehabilitation initiation, integrating psychological support into rehabilitation programs, and developing continuous education programs for patients and families represent strategic steps that need to be implemented to optimize functional outcomes and quality of life for lower limb amputation patients in Sudan.

6. Conflict of interest

All authors declare no conflict of interest.

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