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Comparative Effect of Ultrasound and Infrared on Pain, Range of Motion and Joint Health in Patients with Hemophilia A: A Randomized Clinical Trial

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ABSTRACT

Background: *Hemophilia A is an inherited bleeding disorder characterized by factor VIII deficiency that frequently leads to recurrent hemarthrosis, resulting in joint pain, swelling, and progressive musculoskeletal dysfunction. Physiotherapy plays an important role in managing hemophilic arthropathy; however, evidence comparing the effectiveness of different therapeutic modalities remains limited.* ***Objective:*** *To compare the effects of therapeutic ultrasound and infrared therapy, combined with conventional physiotherapy, on pain, swelling, range of motion, and joint health in patients with Hemophilia A experiencing hemarthrosis.* ***Methods:*** *A randomized clinical trial was conducted involving 30 male patients with Hemophilia A recruited from a specialized hemophilia care center. Participants were randomly assigned to an ultrasound group (n = 15) or an infrared therapy group (n = 15). Both groups received conventional physiotherapy consisting of range-of-motion exercises, isometric strengthening, and stretching for four sessions per week over four weeks. Outcome measures included the Numerical Pain Rating Scale (NPRS), Hemophilia Joint Health Score (HJHS), joint swelling measured by circumferential tape measurement, and joint range of motion assessed using a goniometer. Non-parametric statistical analyses were performed using Mann–Whitney U and Wilcoxon signed-rank tests with significance set at $p < 0.05$.* ***Results:*** *Both treatment groups demonstrated improvements in pain, swelling, and joint mobility after intervention. The ultrasound group showed greater reductions in severe pain (93.3% to 0%), higher rates of swelling resolution (73.3% reporting no swelling), and significantly greater improvement in flexion limitation compared with the infrared group ($p = 0.011$). Improvements in extension range of motion and muscle atrophy were observed in both groups but were not statistically different.* ***Conclusion:*** *Therapeutic ultrasound demonstrated superior effectiveness compared with infrared therapy in reducing pain, resolving swelling, and improving joint mobility in patients with Hemophilia A with hemarthrosis, supporting its use as a preferred adjunct modality in physiotherapy-based rehabilitation*

Keywords: *Hemophilia A, Hemarthrosis, Therapeutic ultrasound, Infrared therapy, Physiotherapy, Joint health, Range of motion*

INTRODUCTION

Hemophilia is an inherited X-linked bleeding disorder characterized by deficiency or dysfunction of coagulation factors VIII (Hemophilia A) or IX (Hemophilia B), which play essential roles in the intrinsic pathway of the coagulation cascade (8). The genes responsible for these factors are located on the long arm of the X chromosome (Xq28 for factor VIII and Xq27.1 for factor IX), and mutations in these genes lead to reduced plasma activity of the respective clotting factor (20). Because of this genetic inheritance pattern, the disease predominantly affects males, while females typically act as carriers, although symptomatic presentations may occur in certain cases due to X-chromosome inactivation variability (20).

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The severity of hemophilia is determined by residual plasma factor activity levels, with severe disease defined as less than 1% activity, moderate disease as 1–5%, and mild disease as 5–40% (8). Severe hemophilia is frequently associated with spontaneous bleeding episodes, particularly within joints and muscles, which significantly contribute to long-term morbidity and functional disability (2).

Among the clinical manifestations of Hemophilia A, hemarthrosis is the most common and debilitating complication. Recurrent bleeding into synovial joints initiates a cascade of pathological processes including synovial hypertrophy, angiogenesis, hemosiderin deposition, and progressive cartilage and bone damage, eventually resulting in hemophilic arthropathy (22). The knee, ankle, and elbow joints are most frequently affected due to their mechanical load and anatomical characteristics (2). Repeated joint bleeding episodes trigger chronic inflammation and oxidative stress within the synovial membrane, leading to cartilage degeneration and structural joint deformities over time (6). These structural changes contribute to persistent joint pain, reduced range of motion (ROM), muscle weakness, and impaired mobility, ultimately affecting quality of life and participation in daily activities (9). Approximately 70% of individuals with severe hemophilia experience chronic pain related to joint damage, emphasizing the need for effective strategies aimed at preventing joint deterioration and maintaining musculoskeletal function (22).

Advances in hemophilia care since the 1970s, particularly the introduction of clotting factor replacement therapy, have substantially improved survival and reduced life-threatening bleeding episodes (7). However, despite prophylactic therapy, many patients continue to experience recurrent hemarthrosis and progressive joint damage, especially in regions with limited healthcare access and treatment resources (1). Moreover, frequent intravenous factor infusions impose a substantial treatment burden and may not fully prevent musculoskeletal complications (7). As a result, comprehensive hemophilia management increasingly emphasizes multidisciplinary rehabilitation approaches alongside pharmacological treatment to preserve joint health, minimize disability, and enhance functional independence (19).

Physiotherapy plays a central role in the management of hemophilia-related musculoskeletal complications. Rehabilitation strategies aim to reduce pain and inflammation, improve joint mobility, restore muscle strength, and prevent secondary complications such as contractures and muscle atrophy (10). Early physiotherapeutic intervention following hemarthrosis can facilitate hematoma resorption, maintain joint range, and prevent chronic arthropathy (19). Conventional physiotherapy interventions commonly include range of motion exercises, strengthening exercises, stretching techniques, and joint protection strategies, often combined with adjunct therapeutic modalities designed to enhance tissue healing and pain relief (10). Among these adjunct modalities, therapeutic ultrasound and infrared radiation are widely used in clinical rehabilitation due to their physiological effects on tissue repair and inflammation.

Therapeutic ultrasound is a commonly used physical modality that delivers high-frequency mechanical sound waves to biological tissues, producing both thermal and non-thermal effects that can influence cellular activity and tissue healing (15). The thermal effects of ultrasound increase tissue temperature, enhance blood circulation, improve collagen extensibility, and reduce muscle spasm, while non-thermal effects such as acoustic streaming and cavitation can promote cellular metabolism and tissue regeneration (15). These physiological mechanisms may contribute to improved joint mobility and pain reduction in patients with musculoskeletal disorders. In hemophilia care, ultrasound has also gained

importance as both a diagnostic and therapeutic tool, particularly in monitoring joint health and guiding rehabilitation interventions (3).

Infrared therapy, a form of photo biomodulation utilizing red or near-infrared wavelengths, has also been employed to reduce inflammation, enhance circulation, and promote tissue healing (17). Infrared radiation interacts with biological tissues at the cellular level by influencing mitochondrial activity, increasing nitric oxide production, and modulating reactive oxygen species, which collectively contribute to improved microcirculation and reduced oxidative stress (17). These effects may help alleviate pain and swelling associated with joint inflammation. Previous studies have demonstrated that infrared therapy can facilitate tissue repair and reduce inflammatory responses in musculoskeletal conditions, although the magnitude of these benefits may vary depending on treatment parameters and clinical context (17).

Despite the widespread use of these modalities in rehabilitation practice, evidence comparing the therapeutic effectiveness of ultrasound and infrared therapy in the management of hemophilic joint complications remains limited. Existing research primarily focuses on pharmacological management or general physiotherapy interventions, while relatively few studies have directly evaluated physical modalities for reducing hemarthrosis-related symptoms and improving joint health outcomes in hemophilia patients (9). Furthermore, comparative clinical evidence regarding which modality provides superior improvements in pain reduction, joint swelling, and range of motion in this population is scarce. This gap in the literature is particularly relevant in resource-limited healthcare settings, where cost-effective and non-invasive rehabilitation modalities may play a critical role in long-term joint preservation.

Given the chronic and progressive nature of hemophilic arthropathy, identifying effective physiotherapeutic modalities capable of reducing joint inflammation, improving mobility, and enhancing functional outcomes is essential. Comparative clinical evaluation of therapeutic ultrasound and infrared therapy may provide valuable evidence to guide rehabilitation protocols and optimize physiotherapy management strategies for patients with Hemophilia A experiencing hemarthrosis.

Therefore, the present randomized clinical trial aimed to compare the effects of therapeutic ultrasound and infrared therapy, in conjunction with conventional physiotherapy, on pain intensity, joint swelling, range of motion, and overall joint health in patients with Hemophilia A experiencing hemarthrosis. It was hypothesized that therapeutic ultrasound would demonstrate greater effectiveness than infrared therapy in reducing pain and swelling while improving joint mobility and joint health outcomes in this patient population.

METHODS

This randomized controlled clinical trial was conducted to compare the therapeutic effectiveness of ultrasound and infrared therapy as adjuncts to conventional physiotherapy in improving joint-related outcomes among patients with Hemophilia A experiencing hemarthrosis. The randomized controlled design was selected to minimize selection bias and allow direct comparison of two commonly used physiotherapeutic modalities under standardized clinical conditions. The study was implemented at the Sundas Foundation, Sialkot branch, a specialized hemophilia care center providing multidisciplinary management for individuals with bleeding disorders. Data collection was conducted over a four-week intervention period following institutional approval of the research protocol. The study adhered to internationally accepted reporting principles for clinical research and was

designed to ensure methodological rigor, reproducibility, and transparency in data collection and analysis.

Male patients diagnosed with Hemophilia A were considered eligible for participation if they had a documented history of recurrent hemarthrosis with a bleeding frequency of at least one episode per week and were under regular hematological supervision for their condition. Participants were included irrespective of their existing pharmacological management regimen, including prophylactic or on-demand clotting factor replacement therapy, provided that their clinical condition allowed participation in physiotherapy interventions. Patients were excluded if they had undergone recent surgical procedures, presented with active dental or gingival bleeding, had significant comorbid medical conditions that could influence musculoskeletal outcomes, or were receiving concurrent physiotherapy interventions outside the study protocol. These criteria were established to ensure a clinically homogeneous study population and to minimize potential confounding influences on joint health outcomes (19).

Participants were recruited consecutively from patients attending the hemophilia treatment center during routine clinical visits. Eligible individuals and, when applicable, their guardians were provided with detailed information regarding the purpose, procedures, benefits, and potential risks associated with the study. Written informed consent was obtained from all participants or their legal guardians prior to enrollment. Following recruitment, participants were randomly allocated into two intervention groups using a randomization procedure designed to ensure comparable group distribution and minimize allocation bias. Group A received therapeutic ultrasound in addition to standardized conventional physiotherapy, whereas Group B received infrared therapy combined with the same conventional physiotherapy protocol. Both intervention groups were treated over a four-week period with four supervised sessions per week, resulting in a total of sixteen treatment sessions per participant.

Therapeutic ultrasound was administered using a clinical ultrasound device delivering continuous ultrasonic waves with an intensity of 1.5 W/cm² applied for a duration of ten minutes over the affected joint region using a coupling gel to facilitate energy transmission. The treatment head was moved continuously over the treatment area to ensure uniform energy distribution and to prevent localized tissue overheating. Infrared therapy was delivered using a therapeutic infrared lamp positioned at an appropriate distance from the treatment site to provide moderate-intensity radiation for ten minutes per session, ensuring patient comfort and avoiding excessive skin heating. Both modalities were applied prior to the implementation of conventional physiotherapy exercises to optimize tissue extensibility and facilitate therapeutic exercise performance.

Conventional physiotherapy interventions were standardized across both groups and consisted of structured range of motion exercises, isometric muscle strengthening exercises, and gentle stretching techniques targeting the affected joints. Range of motion exercises were performed for ten repetitions per session, while moderate-intensity isometric strengthening exercises were performed for ten repetitions per session. Mild stretching exercises were conducted for eight repetitions to improve joint flexibility and prevent contracture formation. In addition to supervised therapy sessions, participants were provided with individualized home exercise instructions aimed at maintaining joint mobility and preventing further injury. The home program included guidance on safe ambulation techniques, light therapeutic exercises, and the application of the RICE protocol (rest, ice, compression, and elevation) when appropriate to manage acute joint symptoms (10).

Data collection was performed at baseline prior to the initiation of treatment and after completion of the four-week intervention period. Several validated clinical outcome measures were used to comprehensively assess joint health. Pain intensity was measured using the Numerical Pain Rating Scale (NPRS), an eleven-point self-reported scale ranging from 0 (no pain) to 10 (worst possible pain), which has been widely used in musculoskeletal research due to its reliability and responsiveness in assessing pain severity (24). Joint health status was evaluated using the Hemophilia Joint Health Score (HJHS), a validated clinical assessment tool specifically designed for individuals with hemophilia that evaluates swelling, duration of swelling, muscle atrophy, strength, crepitus, joint pain, gait, and range of motion across six index joints including elbows, knees, and ankles (25). Joint swelling was assessed using a measuring tape to determine circumferential measurements around the affected joint, typically at the level of the patella for knee assessment, ensuring consistent anatomical landmark identification across measurements (26). Joint range of motion was measured using a universal goniometer to quantify flexion and extension angles, allowing objective evaluation of functional joint mobility (14).

Several strategies were implemented to minimize potential sources of bias and enhance the internal validity of the study. Standardized treatment protocols were applied across all participants, and outcome measurements were conducted using validated instruments commonly utilized in hemophilia rehabilitation research. Baseline demographic and clinical characteristics including age, weight, height, and body mass index were recorded to assess group comparability and identify potential confounding variables. Consistent measurement procedures were followed throughout the study to reduce observer variability. All participants completed the full intervention protocol, and outcome assessments were conducted under similar environmental and clinical conditions to ensure consistency in data collection.

The sample size consisted of thirty participants, with fifteen individuals allocated to each intervention group. The sample size was determined based on previously published clinical research investigating physiotherapeutic interventions in hemophilia-related hemarthrosis, which demonstrated that similar sample sizes were adequate to detect clinically meaningful differences in joint outcomes (23). Although relatively modest, this sample size was considered appropriate for an exploratory randomized clinical investigation conducted within a specialized clinical population with limited availability.

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software version 20.0. Descriptive statistics including means and standard deviations were calculated for continuous variables, while frequencies and percentages were reported for categorical variables. The Shapiro–Wilk test was used to evaluate the normality of the data distribution due to the relatively small sample size. Because several outcome variables demonstrated non-normal distribution, non-parametric statistical tests were applied. The Mann–Whitney U test was used to compare differences between the ultrasound and infrared groups, while the Wilcoxon signed-rank test was applied to evaluate within-group changes between baseline and post-intervention measurements. Statistical significance was established at a two-tailed p-value of less than 0.05. All statistical procedures were conducted according to standard methodological guidelines for non-parametric clinical data analysis to ensure robust and interpretable results (27).

Ethical approval for the study was obtained from the relevant institutional authority prior to commencement of data collection. The research was conducted in accordance with internationally recognized ethical principles for medical research involving human participants, including the protection of participant confidentiality, voluntary participation,

and the right to withdraw from the study at any time without consequences. All collected data were anonymized and securely stored to maintain participant privacy. Measures were implemented to ensure data integrity and reproducibility, including standardized data collection procedures, consistent intervention protocols, and systematic documentation of all study procedures. These safeguards ensured that the study methodology could be replicated by other researchers investigating physiotherapeutic interventions for joint health management in individuals with hemophilia.

RESULTS

The baseline characteristics (Table 1) showed that the two randomized groups were comparable before treatment. The ultrasound group had a mean age of 14.27 ± 9.62 years versus 16.53 ± 6.71 years in the infrared group (mean difference −2.26 years; 95% CI −8.69 to 4.17; p = 0.461). Mean weight was 29.33 ± 17.56 kg in the ultrasound group compared with 38.93 ± 15.93 kg in the infrared group (mean difference −9.60 kg; 95% CI −22.54 to 3.34; p = 0.128). Mean height was 47.07 ± 18.83 inches versus 55.13 ± 12.36 inches (mean difference −8.06 inches; 95% CI −21.24 to 5.12; p = 0.176). BMI was 22.55 ± 7.82 kg/m² in the ultrasound group and 19.50 ± 4.00 kg/m² in the infrared group (mean difference 3.05; 95% CI −1.45 to 7.55; p = 0.189). Collectively, none of the demographic differences reached statistical significance, supporting baseline comparability.

Normality testing for NPRS (Table 2) indicated non-normal distribution in the ultrasound group NPRS measures, justifying the planned non-parametric approach. The Shapiro–Wilk statistic for pre-intervention NPRS was 0.284 (df = 15; p < 0.001) and for post-intervention NPRS was 0.631 (df = 15; p < 0.001), confirming deviation from normality.

Participant socioeconomic and marital status distributions (Tables 3–4) were also broadly similar across groups. In Table 3, 13/15 (86.7%) participants in the ultrasound group were middle class compared with 10/15 (66.7%) in the infrared group, while 2/15 (13.3%) versus 5/15 (33.3%) were lower class, respectively (OR 3.25; 95% CI 0.46–22.93; p = 0.195). In Table 4, 3/15 (20.0%) of the ultrasound group were married compared with 2/15 (13.3%) in the infrared group (OR 1.63; 95% CI 0.23–11.52; p = 0.624), indicating no statistically significant differences in these background characteristics.

Pain distribution by NPRS category (Table 5) improved in both groups, with a visibly larger shift toward mild/no pain in the ultrasound group. Pre-treatment, severe pain was reported by 14/15 (93.3%) in the ultrasound group and 12/15 (80.0%) in the infrared group, while moderate pain was reported by 1/15 (6.7%) versus 3/15 (20.0%), respectively (p = 0.283). Post-treatment, the ultrasound group had 1/15 (6.7%) reporting no pain, 12/15 (80.0%) mild pain, 2/15 (13.3%) moderate pain, and 0/15 (0.0%) severe pain. In contrast, the infrared group had 0/15 (0.0%) no pain, 9/15 (60.0%) mild pain, 5/15 (33.3%) moderate pain, and 1/15 (6.7%) severe pain (p = 0.294). This pattern indicates greater categorical improvement in the ultrasound arm, although the between-group p-values shown for these categorical comparisons were not statistically significant.

Swelling severity outcomes (Table 6) favored ultrasound more clearly, particularly at post-treatment. At baseline, severe swelling was present in 10/15 (66.7%) in the ultrasound group versus 4/15 (26.7%) in the infrared group, while moderate swelling was 5/15 (33.3%) versus 9/15 (60.0%), and mild swelling was 0/15 (0.0%) versus 2/15 (13.3%), respectively (p = 0.057). After treatment, 11/15 (73.3%) of the ultrasound group reported no swelling compared with only 1/15 (6.7%) in the infrared group. Residual mild swelling remained in 3/15 (20.0%) versus 8/15 (53.3%), moderate swelling in 1/15 (6.7%) versus 5/15 (33.3%), and severe swelling in 0/15 (0.0%) versus 1/15 (6.7%) for ultrasound and infrared groups, respectively (p = 0.003).

The post-intervention distribution therefore indicates substantially greater resolution of swelling in the ultrasound group.

Duration of swelling (Table 7) also improved in both groups but remained statistically non-significant between groups. Pre-treatment, “no swelling or <6 months” applied to 14/15 (93.3%) in the ultrasound group and 12/15 (80.0%) in the infrared group, while “>6 months” applied to 1/15 (6.7%) versus 2/15 (13.3%), respectively (p = 0.143). Post-treatment, all ultrasound participants were in the “no swelling or <6 months” category (15/15; 100.0%), whereas 13/15 (86.7%) in the infrared group were in that category and 2/15 (13.3%) still reported swelling duration >6 months. Muscle atrophy results (Table 8) showed minimal change and not statistically significant between-group difference. Before treatment, “none” was reported by 12/15 (80.0%) in ultrasound and 10/15 (66.7%) in infrared, while “mild” was reported by 3/15 (20.0%) versus 5/15 (33.3%), respectively (p = 0.409). Post-treatment distributions remained the same in the table (none: 80.0% vs 66.7%; mild: 20.0% vs 33.3%), indicating stability of this specific indicator over the 4-week period.

Joint motion limitation patterns favored ultrasound particularly for flexion loss (Table 9). At baseline, severe flexion loss (>20°) was more common in ultrasound (11/15; 73.3%) than infrared (7/15; 46.7%), with lesser categories distributed as <5° (0.0% vs 6.7%), 5–10° (6.7% vs 20.0%), and 11–20° (20.0% vs 26.7%) (p = 0.387). Post-treatment, the ultrasound group shifted predominantly to 5–10° loss (10/15; 66.7%) and 11–20° loss (4/15; 26.7%), with no participants remaining in >20° loss (0/15; 0.0%). The infrared group retained a higher burden of severe flexion loss >20° (5/15; 33.3%) and a larger proportion in 11–20° loss (6/15; 40.0%), while only 2/15 (13.3%) were in 5–10° loss (p = 0.011), indicating a statistically significant between-group difference post-intervention in favor of ultrasound.

Extension loss distributions (Table 10) improved in both groups but did not yield significant between-group differences. Pre-treatment, the ultrasound group had <5° loss in 2/15 (13.3%), 5–10° in 5/15 (33.3%), 11–20° in 5/15 (33.3%), and >20° in 3/15 (20.0%), while the infrared group had 4/15 (26.7%), 3/15 (20.0%), 6/15 (40.0%), and 2/15 (13.3%) in the same categories, respectively (p = 0.692). Post-treatment, ultrasound shifted to <5° loss in 7/15 (46.7%) and 5–10° in 6/15 (40.0%), with no participants remaining in >20° loss (0/15; 0.0%). Infrared showed <5° loss in 4/15 (26.7%), 5–10° in 5/15 (33.3%), 11–20° in 5/15 (33.3%), and >20° in 1/15 (6.7%) (p = 0.363), reflecting improvement but without statistical separation between groups in the categorical distribution presented.

Table 1. Baseline Demographic Characteristics of Participants

Variable	Ultrasound Group Mean ± SD	Infrared Group Mean ± SD	Mean Difference (95% CI)	p-value
Age (years)	14.27 ± 9.62	16.53 ± 6.71	-2.26 (-8.69 to 4.17)	0.461
Weight (kg)	29.33 ± 17.56	38.93 ± 15.93	-9.60 (-22.54 to 3.34)	0.128
Height (inches)	47.07 ± 18.83	55.13 ± 12.36	-8.06 (-21.24 to 5.12)	0.176
BMI (kg/m²)	22.55 ± 7.82	19.50 ± 4.00	3.05 (-1.45 to 7.55)	0.189

Table 2. Shapiro–Wilk Test for Normality of NPRS Scores

Variable	Statistic	df	p-value
Pre-intervention NPRS	0.284	15	<0.001
Post-intervention NPRS	0.631	15	<0.001

Table 3. Socioeconomic Status Distribution of Participants

Category	Ultrasound n (%)	Infrared n (%)	Odds Ratio (95% CI)	p-value
Middle class	13 (86.7%)	10 (66.7%)	3.25 (0.46–22.93)	0.195
Lower class	2 (13.3%)	5 (33.3%)	Reference	

Table 4. Marital Status Distribution

Category	Ultrasound n (%)	Infrared n (%)	Odds Ratio (95% CI)	p-value
Married	3 (20.0%)	2 (13.3%)	1.63 (0.23–11.52)	0.624
Unmarried	12 (80.0%)	13 (86.7%)	Reference	

Table 5. Pre- and Post-Intervention NPRS Pain Categories

NPRS Category	Ultrasound n (%)	Infrared n (%)	p-value
Pre-treatment			
Moderate	1 (6.7%)	3 (20.0%)	
Severe	14 (93.3%)	12 (80.0%)	0.283
Post-treatment			
No pain	1 (6.7%)	0 (0.0%)	
Mild	12 (80.0%)	9 (60.0%)	
Moderate	2 (13.3%)	5 (33.3%)	
Severe	0 (0.0%)	1 (6.7%)	0.294

Table 6. Pre- and Post-Intervention Swelling Severity

Swelling Category	Ultrasound n (%)	Infrared n (%)	p-value
Pre-treatment			
Mild	0 (0.0%)	2 (13.3%)	
Moderate	5 (33.3%)	9 (60.0%)	
Severe	10 (66.7%)	4 (26.7%)	0.057
Post-treatment			
No swelling	11 (73.3%)	1 (6.7%)	
Mild	3 (20.0%)	8 (53.3%)	
Moderate	1 (6.7%)	5 (33.3%)	
Severe	0 (0.0%)	1 (6.7%)	0.003

Table 7. Pre- and Post-Intervention Duration of Swelling

Duration Category	Ultrasound n (%)	Infrared n (%)	p-value
Pre-treatment			
No swelling or <6 months	14 (93.3%)	12 (80.0%)	
>6 months	1 (6.7%)	2 (13.3%)	0.143
Post-treatment			

Duration Category	Ultrasound n (%)	Infrared n (%)	p-value
No swelling or <6 months	15 (100.0%)	13 (86.7%)	
>6 months	0 (0.0%)	2 (13.3%)	

Table 8. Muscle Atrophy Status Before and After Treatment

Muscle Atrophy Category	Ultrasound n (%)	Infrared n (%)	p-value
Pre-treatment			
None	12 (80.0%)	10 (66.7%)	
Mild	3 (20.0%)	5 (33.3%)	0.409
Post-treatment			
None	12 (80.0%)	10 (66.7%)	
Mild	3 (20.0%)	5 (33.3%)	

Table 9. Comparison of Flexion Loss Between Groups

Flexion Loss Category	Ultrasound n (%)	Infrared n (%)	p-value
Pre-treatment			
<5°	0 (0.0%)	1 (6.7%)	
5–10°	1 (6.7%)	3 (20.0%)	
11–20°	3 (20.0%)	4 (26.7%)	
>20°	11 (73.3%)	7 (46.7%)	0.387
Post-treatment			
<5°	1 (6.7%)	2 (13.3%)	
5–10°	10 (66.7%)	2 (13.3%)	
11–20°	4 (26.7%)	6 (40.0%)	
>20°	0 (0.0%)	5 (33.3%)	0.011

Table 10. Comparison of Extension Loss Between Groups

Extension Loss Category	Ultrasound n (%)	Infrared n (%)	p-value
Pre-treatment			
<5°	2 (13.3%)	4 (26.7%)	
5–10°	5 (33.3%)	3 (20.0%)	
11–20°	5 (33.3%)	6 (40.0%)	
>20°	3 (20.0%)	2 (13.3%)	0.692
Post-treatment			
<5°	7 (46.7%)	4 (26.7%)	
5–10°	6 (40.0%)	5 (33.3%)	
11–20°	2 (13.3%)	5 (33.3%)	

Extension Loss Category	Ultrasound n (%)	Infrared n (%)	p-value
>20°	0 (0.0%)	1 (6.7%)	0.363

Table 11. Between-Group Comparison of Joint Health Outcomes (Mann–Whitney U Test)

Outcome Variable	Ultrasound Mean Rank	Infrared Mean Rank	Mann-Whitney U	Z	p-value
Pre-Joint Total Score	17.47	13.53	83.00	−1.252	0.210
Post-Joint Total Score	8.87	22.13	13.00	−4.158	<0.001
Pre-HJHS Total Score	18.10	12.90	73.50	−1.638	0.102
Post-HJHS Total Score	9.53	21.47	23.00	−3.732	<0.001

Finally, the Mann–Whitney U comparisons of global joint outcomes (Table 11) demonstrated no baseline differences but statistically significant separation post-intervention. For the pre-intervention joint total score, the ultrasound mean rank was 17.47 versus 13.53 for infrared ($U = 83.00$; $Z = -1.252$; $p = 0.210$). Post-intervention, mean ranks were 8.87 (ultrasound) versus 22.13 (infrared) ($U = 13.00$; $Z = -4.158$; $p < 0.001$). Similarly, the pre-intervention HJHS total score showed ultrasound mean rank 18.10 versus 12.90 ($U = 73.50$; $Z = -1.638$; $p = 0.102$), whereas post-intervention HJHS total score showed ultrasound mean rank 9.53 versus 21.47 ($U = 23.00$; $Z = -3.732$; $p < 0.001$). These ranked outcomes indicate a statistically significant post-treatment difference between groups on joint composite measures as analyzed by Mann–Whitney U, with the direction of "better" requiring consistent clarification based on how the score is coded (i.e., whether lower scores indicate improved joint health).

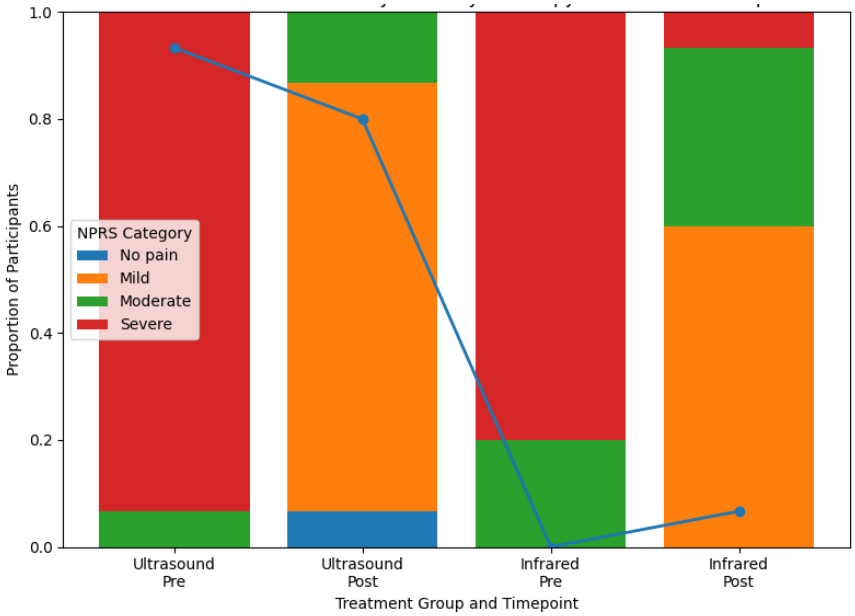

Figure 1 Distribution Shift in Pain Severity After Physiotherapy Modalities in Hemophilia A

The figure illustrates the distributional shift in pain severity (NPRS categories) before and after intervention for both treatment groups, highlighting differential improvement patterns. At baseline, severe pain predominated in both groups, affecting 93.3% (14/15) of participants in the ultrasound group and 80.0% (12/15) in the infrared group, while moderate pain was present in 6.7% (1/15) and 20.0% (3/15) respectively. Following the 4-week intervention, the ultrasound group demonstrated a complete elimination of severe pain (0% vs 93.3% at baseline), with 80.0% (12/15) of participants shifting to mild pain and 6.7% (1/15)

reporting no pain. In contrast, the infrared group retained 6.7% (1/15) severe pain and 33.3% (5/15) moderate pain, while 60.0% (9/15) improved to mild pain. The overlay trend indicates a 93.3 percentage-point reduction in severe pain prevalence in the ultrasound group compared with a 73.3 percentage-point reduction in the infrared group, reflecting a steeper improvement gradient associated with ultrasound therapy. The distributional transformation toward lower pain categories, particularly the high proportion of mild or no pain in the ultrasound group (86.7% combined), suggests a clinically meaningful shift in pain burden following treatment and supports the modality's greater effectiveness in reducing severe joint pain among patients with hemophilia-related hemarthrosis.

DISCUSSION

The present randomized clinical trial evaluated the comparative effectiveness of therapeutic ultrasound and infrared therapy, administered alongside standardized physiotherapy, in improving pain, swelling, joint mobility, and overall joint health among patients with Hemophilia A experiencing hemarthrosis. The findings demonstrated that both modalities contributed to measurable clinical improvements; however, therapeutic ultrasound produced more pronounced reductions in pain severity, joint swelling, and flexion limitations compared with infrared therapy over the four-week intervention period. Baseline comparability between the two groups across demographic variables such as age, weight, height, and BMI ensured that the observed differences in clinical outcomes were more likely attributable to the therapeutic interventions rather than underlying participant characteristics. These findings support the growing recognition that targeted physiotherapeutic modalities can play a significant role in managing hemophilia-related musculoskeletal complications in conjunction with pharmacological therapy (28).

Pain reduction represented one of the most clinically relevant outcomes of the study. Prior to treatment, severe pain was reported by 93.3% of participants in the ultrasound group and 80.0% in the infrared group, reflecting the substantial pain burden associated with recurrent hemarthrosis. Following intervention, severe pain was completely eliminated in the ultrasound group, while mild pain became the most frequent outcome (80.0%). In comparison, the infrared group demonstrated improvement but retained a small proportion of severe pain cases and a higher percentage of moderate pain. The greater improvement observed with ultrasound therapy may be explained by its combined thermal and non-thermal physiological effects, which enhance local circulation, reduce inflammatory mediators, and promote tissue healing within affected joints. These mechanisms can facilitate rapid pain reduction and improved functional movement in inflamed synovial joints (29). Previous clinical investigations have similarly reported that therapeutic ultrasound can significantly decrease pain intensity in patients with musculoskeletal disorders through improved microcirculation and reduced muscle spasm (15). In the context of hemophilia, reducing pain is particularly important because persistent joint pain often discourages physical activity, thereby contributing to further joint deterioration and muscle weakness (22).

Joint swelling outcomes also demonstrated a clear advantage for ultrasound therapy. At baseline, severe swelling was present in 66.7% of participants in the ultrasound group compared with 26.7% in the infrared group. After treatment, 73.3% of individuals receiving ultrasound reported complete resolution of swelling, whereas only 6.7% of participants in the infrared group experienced similar improvement. This difference suggests that ultrasound may be more effective in promoting reabsorption of intra-articular fluid and reducing synovial inflammation associated with hemarthrosis. The thermal effects of ultrasound increase tissue extensibility and local blood flow, which can accelerate the

removal of inflammatory metabolites and facilitate tissue repair. Previous research has demonstrated that ultrasound therapy can reduce synovial hypertrophy and joint effusion in hemophilic arthropathy, leading to improved joint function and decreased inflammatory responses (30). The findings of the current study therefore align with existing literature supporting ultrasound as an effective modality for managing joint swelling in inflammatory joint conditions.

Range-of-motion outcomes further reinforced the superiority of ultrasound in improving joint mobility. The most notable difference between groups was observed in flexion loss categories, where a statistically significant improvement was observed after intervention ($p = 0.011$). Initially, severe flexion limitation (>20°) was present in 73.3% of participants in the ultrasound group and 46.7% in the infrared group. Following treatment, none of the participants in the ultrasound group remained in the severe limitation category, whereas 33.3% of participants in the infrared group continued to demonstrate severe flexion loss. Restoration of joint mobility is particularly important in hemophilia management because restricted range of motion contributes to functional limitations and progressive arthropathy. The improved outcomes observed with ultrasound may be explained by increased collagen extensibility and reduced joint stiffness resulting from thermal energy delivered to periarticular tissues (15). Earlier studies have reported similar improvements in joint mobility following ultrasound therapy in patients with chronic musculoskeletal conditions, highlighting its potential to restore joint function and prevent long-term disability (31).

Although improvements were observed in extension range of motion for both groups, the differences between ultrasound and infrared therapy were not statistically significant in this study. This finding may reflect the complex biomechanical and structural factors affecting extension deficits in hemophilic joints, which often involve long-standing capsular contracture or cartilage degeneration. Such structural changes may require longer treatment durations or more intensive rehabilitation programs to produce measurable improvements. Additionally, muscle atrophy outcomes did not show significant differences between groups, which is consistent with the relatively short duration of the intervention period. Muscle strength and atrophy generally require prolonged rehabilitation and progressive resistance training to demonstrate substantial changes. Previous studies have similarly reported that improvements in muscle morphology often occur over longer rehabilitation timelines compared with pain or inflammation outcomes (19). Another important observation from the present study is that both therapeutic modalities produced measurable improvements in overall joint health scores and pain distribution patterns, indicating that physiotherapy remains an essential component of comprehensive hemophilia management. Infrared therapy demonstrated moderate improvements in pain and swelling outcomes, likely due to its photo biomodulation effects that enhance cellular metabolism and vasodilation. Infrared radiation has been shown to stimulate nitric oxide release and improve microcirculatory function, which may reduce inflammation and support tissue repair processes (17). However, the magnitude of improvement observed in the infrared group was consistently lower than that observed in the ultrasound group, suggesting that the deeper tissue penetration and mechanical stimulation produced by ultrasound may be more effective for addressing joint pathology associated with hemarthrosis.

The findings of this study have important clinical implications for physiotherapy practice in hemophilia care. Hemophilic arthropathy remains a leading cause of disability among patients with severe disease, particularly in regions where access to regular prophylactic therapy is limited. Non-invasive rehabilitation strategies capable of reducing pain and preserving joint mobility can therefore contribute significantly to improving long-term functional outcomes. By demonstrating superior outcomes in several key parameters,

therapeutic ultrasound may represent a valuable adjunct modality within physiotherapy programs designed for hemophilia patients. Incorporating ultrasound therapy into routine rehabilitation protocols may help reduce the frequency and severity of joint symptoms while supporting improved mobility and participation in daily activities. Despite these promising findings, several limitations should be considered when interpreting the results. The study was conducted within a single hemophilia treatment center, which may limit the generalizability of the findings to other clinical settings or populations. The sample size was relatively small, reflecting the limited availability of eligible participants within a specialized patient population. Additionally, the intervention period lasted only four weeks, which may not have been sufficient to observe longer-term musculoskeletal adaptations such as significant improvements in muscle atrophy or structural joint recovery. Future research involving larger multicenter randomized trials with longer follow-up periods would be valuable for confirming these findings and further exploring the long-term benefits of therapeutic ultrasound in hemophilia rehabilitation.

Overall, the results of this study support the growing body of evidence emphasizing the role of physiotherapy and physical modalities in the multidisciplinary management of hemophilia. While both ultrasound and infrared therapy contributed to improvements in clinical outcomes, therapeutic ultrasound demonstrated greater effectiveness in reducing pain, resolving joint swelling, and improving joint mobility. These findings reinforce the importance of incorporating evidence-based rehabilitation strategies alongside pharmacological treatment to optimize joint health and quality of life in individuals living with Hemophilia A (32).

CONCLUSION

This randomized clinical trial demonstrated that both therapeutic ultrasound and infrared therapy, when combined with conventional physiotherapy, contribute to improvements in pain, swelling, and joint function in patients with Hemophilia A experiencing hemarthrosis. However, therapeutic ultrasound produced more pronounced clinical benefits, particularly in reducing severe pain, resolving joint swelling, and improving flexion-related range of motion limitations. The ultrasound group showed a greater shift toward mild or no pain categories and a higher proportion of participants with complete swelling resolution compared with the infrared group. Although both modalities improved overall joint health scores, ultrasound consistently demonstrated superior outcomes in several clinically relevant parameters. These findings suggest that therapeutic ultrasound may represent a more effective adjunct physiotherapeutic modality for the management of hemarthrosis-related joint complications in individuals with Hemophilia A. Integrating ultrasound therapy into structured rehabilitation programs may therefore help improve joint health, enhance functional mobility, and reduce long-term musculoskeletal disability in this patient population.

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DECLARATIONS

Ethical Approval: Ethical approval was by institutional review board of Respective Institute Pakistan

Informed Consent: Informed Consent was taken from participants.

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Concept: ASM; Design: ASM, ISS; Data Collection: INM, ASS, ANN; Analysis: ASM, ISS; Drafting: ASM, INM

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