



Effects of transcutaneous electrical nerve stimulation, phonophoresis, and interferential current therapy on hemiplegic shoulder pain among Nigerian stroke survivors

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Abstract. Hemiplegic shoulder pain is a widespread and debilitating symptom experienced by stroke survivors, affecting their rehabilitation outcomes and quality of life. Addressing effective treatment options for this condition is essential to improve patient care. The purpose of this study was to determine how hemiplegic shoulder pain in stroke survivors was affected by phonophoresis, transcutaneous electrical nerve stimulation, and interferential current stimulation. This was a pre- and post-test experimental study conducted among 45 stroke survivors. Hemiplegic shoulder pain was assessed on the Numerical Pain Rating Scale and data were analysed using ANOVA. The results of the study reported a notable variation ($F = 35.101, p < 0.05$) across the physical modalities (transcutaneous electrical nerve stimulator, ultrasound device, and interferential current stimulator) in improving hemiplegic shoulder pain of the subjects. However, phonophoresis was

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found to have superior effect on hemiplegic shoulder pain of stroke survivors, with the post-hoc analysis revealing that phonophoresis is the most promising protocol for treating hemiplegic shoulder pain of stroke survivors. The findings of this study suggest that training clinicians in the proper application of ultrasound devices for phonophoresis can significantly enhance treatment outcomes for hemiplegic shoulder pain in stroke survivors

Keywords: neurological rehabilitation; post-stroke pain; physical modalities; pain modulation

Introduction

Hemiplegic shoulder pain (HSP) is one of the most frequent clinical manifestations following stroke. Along with symptoms of pain, HSP is also accompanied by abnormal muscle tone, reduced grip and shrug strength, and impaired sensation. The occurrence of HSP following a stroke incident can further increase the burden of recovery, limit the functional ability of stroke survivors, and affect their quality of life. Effective management of this condition is crucial as it influences the ability of stroke survivors to regain functionality. Despite the availability of various physical modalities for pain relief, the comparative effectiveness of different treatment protocols is still being explored.

The use of non-pharmacological interventions, such as transcutaneous electrical nerve stimulation (TENS), phonophoresis, and interferential current therapy for the management of chronic pain has gained increased attention. V.C. Whitehair *et al.* [1] examined the acute effects of TENS and transcutaneous neuromuscular electrical stimulation (t-NMES) on pain-free passive range of motion in patients with hemiplegic shoulder pain. The authors found no significant difference in pain-free passive shoulder range of motion between TENS, t-NMES, and the group that received no stimulation. The researchers argued that the shorter duration of electrical stimulation and placement of the electrodes may be responsible for their result. S. Ersoy *et al.* [2] reported that suprascapular nerve blockage, in comparison to TENS, decreased pain scores more significantly among patients with HSP. In contrast to these studies, Y. Li *et al.* [3] investigated the effects of a combined intervention of transcranial Direct Current Stimulation (tDCS) and TENS on HSP, revealing that the combination of tDCS and TENS yielded a greater improvement in pain rating compared to the sole application of tDCS. This finding demonstrated the efficacy of TENS in relieving HSP among stroke survivors. TENS has also been reported to be efficacious in alleviating other chronic pains.

The researchers have also investigated the efficacy of phonophoresis/therapeutic ultrasound in the management of hemiplegic shoulder pain. P. Dajpratham *et al.* [4] compared the efficacy of ultrasound therapy and high-intensity laser therapy for the management of hemiplegic shoulder pain. Their study revealed that ultrasound therapy significantly improved outcomes of pain and shoulder internal rotation among the patients. While both interventions provided comparable analgesic effects, ultrasound therapy demonstrated a greater impact on improving shoulder range of motion (ROM). Additionally, patients who received ultrasound therapy reported a reduced need for analgesic medications compared to those

treated with high-intensity laser therapy. In addition to conventional exercise protocols, F. Eslamian *et al.* [5] compared the efficacy of IFC and electrical acupuncture on shoulder pain among stroke survivors. The group who received electrical acupuncture had better pain improvement compared to the subjects treated with received IFC. While these studies demonstrated the potential of phonophoresis and interferential current in the management of HSP, recent studies notably lack in-depth coverage on the efficacy of these interventions.

However, studies have also demonstrated the efficacy of these physical modalities in the management of other chronic pains. A systematic review by É.P. Rampazo *et al.* [6] on the effects of interferential current in patients with non-specific chronic low back pain reported moderate-quality evidence that interferential current reduces intensity of low back pain as well as disability immediately after treatment, compared to placebo. The researchers also reported low-quality evidence that interferential current therapy reduces pain intensity when compared to TENS. Similarly, K.S. Jung & T.S. In [7] reported that interferential current therapy significantly reduced pain and disability as well as improved balance among patients with chronic low back pain. Another systematic review by F.A. Yang *et al.* [8] on the efficacy of phonophoresis in reducing pain among individuals with knee osteoarthritis, reported that phonophoresis yielded significant reduction in pain scores when compared to therapeutic ultrasound with placebo gel. M.S. Omara *et al.* [9] reported that while both TENS and phonophoresis were efficacious in reducing pain intensity among the subjects, phonophoresis produced more significant effects. A. Oparin *et al.* [10] proposed cryomassage as an alternative therapy for pain management.

To the best of the researchers' knowledge, there is no satisfactory existing database establishing the effects of TENS, phonophoresis, and interferential current therapy on HSP of stroke survivors in Nigeria. Furthermore, basic data on stroke survivors with HSP, which is one of the most challenging manifestations following stroke, are almost non-existent. This suggests the need for academic efforts to provide such data to enhance proper management of HSP among Nigerian clinicians. Notably, it is unclear what the empirical situation has been as to identifying the best modality to adopt in the treatment of HSP in Nigeria. The present study was necessitated by the identified gap in knowledge and research endeavours. It was necessary to compare the effectiveness of TENS, phonophoresis, and IFCS on HSP of Nigerian stroke survivors, which constituted the purpose of the present study.

Materials and Methods

This study employed an experimental design with pre- and post-tests. 66 hemiparetic stroke survivors, ranging within the biological age from 45 to 65, who were treated at the University of Benin Teaching Hospital's Neurology Unit and Physiotherapy Department from July 1 to September 30, 2023, comprised the study's population. 45 stroke survivors with HSP of an average duration of 4 weeks and Numerical Pain Rating Scale (NPRS) between 4 and 10 took part in this study. Subjects were included in this study using purposive sampling technique. Conversely, subjects with acute inflammation of the shoulder joints, peripheral neuropathy, impaired cognition (with score on mini-mental scale lower than 24), and fracture of the upper extremities were excluded from the study. Subsequently, sampling technique employed in the study was a simple randomisation using balloting with replacement to divide the subjects equally into three groups (TENS, IFCS, and the phonophoresis groups). The subjects received analogous analgesics treatment, as directed by their physicians. There was no significant difference in the baseline hemiplegic shoulder pain rating between the control and intervention groups.

TENS is an electrotherapeutic agent used for pain relief. The study employed conventional TENS with high frequency of 150 Hz and a short pulse duration of 100 μ s in the normal mode. Therapeutic ultrasound is an electrophysical agent. The present study employed the 1 MHz frequency. The frequencies used in therapy are normally within 1.0-3.0 MHz (1 MHz = 1 million cycles per second). Furthermore, therapeutic ultrasound was applied to the subjects' hemiplegic shoulders with topical analgesics (ketoprofen) to induce phonophoresis. IFCS is a type of electrical stimulation using paired electrodes from two separate circuits that carry medium-frequency and high-frequency (4,000 Hz) alternating currents. The present study used the

high frequency of 4,000 Hz. NPRS was used to assess different levels of pain. The subjects were prompted to mark a point on a 10 cm line to indicate their pain intensities. All the instruments used in this study were proved scientifically to be standardised, valid, and have good reliability. The validity of the instruments was attested to by specialists in physiotherapy and neurology as suitable for the study. The researchers also cross-checked the instruments and ascertained that their adequate working conditions before use.

Prior to the administration of the instruments, the subjects were given a thorough explanation of the test procedure, along with the goals and specifics of the study, and they were asked to sign an informed consent form before taking part in the study. The committee of research ethics of the University of Benin Teaching Hospital, Nigeria granted ethical approval for the study (ADM/E 22/A/VOL. VII/1483032). The HSP of the subjects was measured prior to and after the 4-week application of the treatment modalities. The difference in the HSP of stroke survivors following application of TENS, phonophoresis, and IFCS was analysed using ANOVA. In addition, Tukey's was employed in instances where significant main or interaction effects of the modalities were identified. A p-value of <0.05 was accepted as statistically significant. Statistical Package for the Social Sciences (SPSS) version 23.0 was used for the analyses performed in the present study.

Results and Discussion

Table 1 displays the results of the ANOVA used to determine the significance of the variation in the subjects' HSP is after TENS, phonophoresis, and IFCS treatment. At 0.05 ($p < 0.05$), the F-value of 35.101 with 5 and 89 degrees of freedom was found to be statistically significant. This suggested that the individuals' HSP was significantly differently affected by the tools. To determine the exact difference, a post-hoc test was to be performed due to this disparity.

Table 1. Analysis of variance (ANOVA) displaying variations in the subjects' HSP after utilising physical modalities

	Sum of squares	Df	Mean square	F	Sig.
Between groups	216.456	5	43.291	35.101	0.000
Within groups	103.600	84	1.233		
Total	320.056	89			

Notes: Df – degree of freedom; Sig. – the two-tailed p-value linked to the null hypothesis that the groups had the same variance; F – the F-test ratio of sample variance

Source: compiled by the authors of this study

The post-hoc test is presented in Table 2. None of the pairwise mean difference comparisons in Table 2 showed statistically significant differences except for pre-IFCS vs post-ultrasound (3.93333'), pre-ultrasound vs post-IFCS (1.26667'), pre-ultrasound vs post-ultrasound (4.66667'), pre-TENS vs post-ultrasound (4.40000'), post-IFCS vs pre-ultrasound (-1.26667'), post-IFCS vs post-ultrasound (3.40000'),

post-ultrasound vs pre-IFCS (-3.93333'), post-ultrasound vs pre-ultrasound (-4.66667'), post-ultrasound vs pre-TENS (-4.40000'), post-ultrasound vs post-IFCS (-3.40000'), post-ultrasound vs post-TENS (-3.53333'), and post-TENS vs post-ultrasound (3.53333'). Accordingly, only the ultrasound (phonophoresis) affected the variation in the subjects' HSP, since the pairwise mean did not have any variables overall.

Table 2. The Tukey's post-hoc test demonstrating variations in the instruments based on the subjects' HSP

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	Sig.
Pre-IFCS	Pre-ultrasound	-0.73333	0.40552	0.466
	Pre-TENS	-0.46667	0.40552	0.858
	Post-IFCS	0.53333	0.40552	0.776
	Post-ultrasound	3.93333*	0.40552	0.000
	Post-TENS	0.40000	0.40552	0.921
Pre-ultrasound	Pre-IFCS	0.73333	0.40552	0.466
	Pre-TENS	0.26667	0.40552	0.986
	Post-IFCS	1.26667*	0.40552	0.029
	Post-ultrasound	4.66667*	0.40552	0.000
	Post-TENS	1.13333	0.40552	0.068
Pre-TENS	Pre-IFCS	0.46667	0.40552	0.858
	Pre-ultrasound	-0.26667	0.40552	0.986
	Post-IFCS	1.00000	0.40552	0.146
	Post-ultrasound	4.40000*	0.40552	0.000
	Post-TENS	0.86667	0.40552	0.279
Post-IFCS	Pre-IFCS	-0.53333	0.40552	0.776
	Pre-ultrasound	-1.26667*	0.40552	0.029
	Pre-TENS	-1.00000	0.40552	0.146
	Post-ultrasound	3.40000*	0.40552	0.000
	Post-TENS	-0.13333	0.40552	0.999
Post-ultrasound	Pre-IFCS	-3.93333*	0.40552	0.000
	Pre-ultrasound	-4.66667*	0.40552	0.000
	Pre-TENS	-4.40000*	0.40552	0.000
	Post-IFCS	-3.40000*	0.40552	0.000
	Post-TENS	-3.53333*	0.40552	0.000
Post-TENS	Pre-IFCS	-0.40000	0.40552	0.921
	Pre-ultrasound	-1.13333	0.40552	0.068
	Pre-TENS	-0.86667	0.40552	0.279
	Post-IFCS	0.13333	0.40552	0.999
	Post-ultrasound	3.53333*	0.40552	0.000

Source: compiled by the authors of this study

Stroke is a debilitating condition and a leading cause of disability globally. H.I. Adebisi *et al.* [11] and M. Duray & E. Baskan [12] reported that stroke substantially affects the upper limb function and grip strength. HSP is one of the widespread complications of stroke and is reported to be common among stroke survivors, with prevalence ranging within 22-47% [13]. According to the present study, there were notable differences ($p < 0.05$) across the physical modalities (transcutaneous electrical nerve stimulator, ultrasound device, and interferential current stimulator) in improving the HSP condition of the subjects. This result aligns with previous findings of M. Moniruzzaman *et al.* [14], D. Suriya-Amarit *et al.* [15], and M. Zhou *et al.* [16], who reported significant effects of these physical modalities in reducing HSP. M. Moniruzzaman *et al.* [14] evaluated the efficacy of both TENS and ultrasound therapy in the management of HSP and reported that both interventions significantly improve pain outcomes among patients with HSP. D. Suriya-Amirat *et al.* [15] reported that patients treated with interferential current reported greater reduction in HSP compared to subjects who received placebo. M. Zhou *et al.* [16] reported that both TENS and neuromuscular electrical stimulation were effective in improving HSP among stroke survivors. The consistency of these

findings with the present study reinforces the efficacy of physical modalities in the management of HSP among stroke survivors. It is hypothesised that these interventions improve pain outcomes through mechanisms such as modulation of nociceptive signals and stimulation of endogenous opioid release. C.G.T. Vance *et al.* [17] and É.P. Rampazo & R.E. Liebano [18] considered these mechanisms in their research. M.K.N. Takla & S.S. Rezk-Allah [19] reflected the enhancement of local blood circulation and muscle relaxation improvements.

The present study found phonophoresis to have superior effect on HSP of stroke survivors. Previous findings reported that phonophoresis significantly improved the HSP of stroke survivors as well as among other populations, such as in patients with myofascial pain syndrome [20, 21]. M.S. Rahman & M.T. Uddin [20] observed that, when administered with pregabalin, therapeutic ultrasound yielded more significant reduction in post-stroke shoulder pain compared to therapeutic ultrasound in isolation. This may be explained by the similarity in the study methodology, including subject characteristics, or correspondence in HSP measuring instruments. Another explanation could also be the affinity in the gradients or clinical characteristics of stroke morbidity. Still, there are

two ways to interpret the substantial improvement in HSP observed in this study after ultrasound therapy. Firstly, the decrease in HSP in this study affirmed the efficacy of ultrasound device in the management of HSP compared with TENS and IFCS. Secondly, the use of topical analgesics (ketoprofen) as coupling medium together with ultrasound device (phonophoresis) could also illustrate the improved HSP noticed in the present study. T. Amornpinyokiat [21] also showed that phonophoresis was more effective in reducing pain in myofascial pain syndrome, compared to conventional ultrasound therapy. This finding further highlighted the improved efficacy in pain reduction following the use of a topical analgesic in combination with ultrasound therapy.

In summary, the present study revealed that the physical modalities of TENS, interferential current therapy, and phonophoresis were efficacious in reducing pain intensity of HSP among stroke survivors. According to the post-hoc analysis, phonophoresis was the most effective of these modalities and offered greater relief of pain compared to interferential current and TENS. The superior result obtained from phonophoresis application in the present study may be attributed to the analgesic effect of ketoprofen used as the coupling medium. The findings of the present study align with those from prior studies that reported the efficacy of physical modalities such as TENS, neuromuscular electrical stimulation, and high-intensity laser therapy.

Conclusions

The findings of the present study revealed that all three physical modalities significantly reduce HSP, with notable differences in their efficacy. Among the interventions, phonophoresis demonstrated superior effectiveness in alleviating HSP. Therefore, phonophoresis is the most

promising protocol in the intervention of HSP of stroke survivors. The combination of topical analgesics (ketoprofen) as coupling medium together with ultrasound device could be the reason why phonophoresis provides superior relief of HSP after stroke compared to TENS and IFC. Thus, clinicians should be trained in the proper usage of physical modalities, especially ultrasound device, for management of HSP of stroke survivors. Limitation of this study lied in the inability to monitor subjects' activities outside the study setting. Specifically, the use of prescribed analgesics and adherence to home programmes were not accounted for, which could have influenced the outcomes. Inadequate clinical examinations also prevented the severity of the stroke from being factored in. Future studies can aim to explore synergistic effects of combining phonophoresis, TENS, or interferential current with other rehabilitation techniques, such as neuromuscular electrical stimulation or manual therapy, to determine if a multi-modal approach yields better outcomes for HSP management. Studies should also investigate the long-term efficacy of pain relief provided by these modalities.

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Conflict of Interest

None.

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Анотація. Геміплегічний біль у плечі – поширений і виснажливий симптом, з яким стикаються люди, що перенесли інсульт, і який впливає на результати їхньої реабілітації та якість життя. Пошук ефективних методів лікування цього стану має важливе значення для покращення догляду за пацієнтами. Метою цього дослідження було визначити, як фонофорез, транскутанна електрична стимуляція нервів та стимуляція інтерференційними струмами впливають на геміплегічний біль у плечі у людей, які пережили інсульт. Було проведено до- і післятестове експериментальне дослідження серед 45 осіб, які пережили інсульт. Геміплегічний біль у плечі оцінювався за числовою шкалою оцінки болю, а дані аналізувалися за допомогою дисперсійного аналізу. Результати дослідження показали значні відмінності ($F = 35,101$, $p < 0,05$) між фізичними методами лікування (транскутанний електричний стимулятор нервів, ультразвуковий пристрій та стимулятор інтерференційного струму) у зменшенні геміплегічного болю в плечі у досліджуваних. Однак було виявлено, що фонофорез має кращий вплив на геміплегічний біль у плечі у людей, які пережили інсульт, а постфактум аналіз показав, що фонофорез є найбільш перспективним протоколом лікування геміплегічного болю в плечі у людей, які пережили інсульт. Результати цього дослідження свідчать про те, що навчання лікарів правильному застосуванню ультразвукових пристроїв для фонофорезу може значно покращити результати лікування геміплегічного болю в плечі у пацієнтів, які пережили інсульт

Ключові слова: неврологічна реабілітація; постінсультний біль; фізичні модальності; модуляція болю