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Effectiveness of Cryokinetics on Functional Independence of Participants with Spinal Cord Injury

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ABSTRACT

This study investigated the effectiveness of cryokinetics on functional independence of participants with spinal cord injury. This study was a pretest – posttest control group experimental design. Thirty-nine participants with spinal cord injury participated inf the study. Participants were randomly assigned into four groups (groups 1, 2, 3 and 4). The 1st group was recognized as the control group while, the 2nd, 3rd and 4th groups were experimental groups. The participants in the control group received conventional daily treatment protocols (usual treatment protocols), the participants in the experimental group 1 received usual treatment protocols plus ST programmes, the participants in the experimental group 2 received usual treatment protocols plus cryotherapy, while the participants in the experimental group 3 received usual treatment protocols plus cryokinetics.

The Quadriplegia Index of Function–Short Form measure (r = 0.987) was used to determine the functional independence of the participants. The adapted cryokinetics protocols were administered to improve the functional independence of the participants. The functional independence of the participants was measured before and after the eight (8) weeks of cryokinetics respectively. One-way analysis of variance was used to analyze the differences in the functional independence of participants with spinal cord injury treated cryokinetics and usual care, compared with the other groups. The finding of this study demonstrated that the cryokinetics in combination with standard care had statistically significant effects on the functional independence of participants with spinal cord injury ($p<0.05$) in comparison with the other groups. It was concluded that the cryokinetics when combined with standard care can substantially improve the functional independence of spinal cord injury patients. We therefore, recommend that cryokinetics combined with standard treatment protocol should be the treatment of choice for patients with spinal cord injury.

Keywords: Cryokinetics; Functionality; Spinal Cord Injury

Introduction

Spinal cord injury (SCI) is an impairment or absence of sensory and or motor function in the cervical, thoracic, lumbar, or sacral spinal segments as a result of damage to the neural elements within the spinal canal (Huang, et al. [1,2]). The functions of the spinal cord are commonly interrupted at the distal level of the injury. There is no reliable estimate of global prevalence of SCI; however, estimated annual global incidence is 40 to 80 cases per a million population WHO [3]. Although the estimated mortality rates of SCI in non-developed countries are relatively low, ranging from 1.4% to 20.0%, however, when and where they occur, their consequences are very devastating. In developed countries, the mortality rates are high and range from 3.1% to 22.2% (Dryden, et al. [4-7]. Patients with SCI usually have permanent and often devastating neurological injuries and associated consequences including muscular weakness, reduced or loss of function, change to bladder, bowel and sexual functions, and loss of functional abilities (Huang, et al. [1,2]). SCI is, emphatically, a life-altering, cataclysmic and costly injury for the affected individuals, their caregivers, families, and society (Huang, et al. [1,2]). The functions of the upper extremity are mostly affiliated with the performance of activities of daily living, as well as social participation. The upper extremities allow for complex task accomplishment in exploration, pretension, precision, reaching, adaptation, perception as well as manipulation. The hand is the main effector of the upper extremity whereas the wrist, elbow, and shoulder joints function to position the hand in space (Harris, et al. [8]).

Walking is of utmost importance to individuals with incomplete SCI in spite of severity and duration of the injury as well as the age of the victims (Bedi, et al. [9]) and a propounding determinant of quality of life. Since SCI causes many disabilities to upper and lower extremities functions, it is important to manage it effectively. One of the treatments commonly used for the management of SCI is Cryokinetics Therapy (Knight, et al. [10]). Cryokinetics is the use of cold treatments with exercise following, resulting in better clinical outcomes such as improved physical quality of life. It also allows the patient to perform exercises sooner and more effectively (Knight, et al. [10]). Using this technique, cold is applied to the affected body part for few minutes, or until the area is numbed, and the patient then performs exercises. Cryokinetics is used to return the injured patients to activity, pain free and fully functional. The process of cryokinetics focuses on controlling pain and inflammation, and regaining normal joint flexibility, muscular strength, muscular endurance, coordination, and power. However, the exact physiological mechanism crykinetics is still unclear. Therapeutic modalities such as cryokinetics and medications are used to create an optimal environment for injury repair by limiting the inflammatory process and breaking the pain-spasm cycle (Knight [11]). Although, assessment of muscular strength and function after strength training (ST) is well documented in the literature (Knight, et al. [10]) however, the evidence supporting the use of cryokinetics in the treatment of SCI is limited. Scientifically, it remains untold, how frequent, or to what extent, ST and cryotherapy are capable of enhancing the functional independence of individuals with SCI. Therefore, this study was aimed at investigating the efficacy of cryokinetics in SCI patients.

Research Question

Will the use of cryokinetics improve functional independence in patients with SCI?

Methods

The pretest - posttest control group experimental design was used in this study. The study population included 60 participants with upper SCI that were admitted at the Division of Neurosurgery, Department of Surgery, University of Benin Teaching Hospital (UBTH), Benin-City (UBTH Medical Record, 2021). Thirty-nine participants with upper incomplete SCI participated in this study. The judgmental sampling technique was employed to recruit the participants for the present study. A simple random sampling technique of balloting with replacement was then used to assign the participants into different groups. The names of the participants were written on pieces of paper and dropped in a bag from where a piece of paper was picked at a time and was assigned randomly into four (4) groups (groups 1, 2, 3 and 4). The first name picked was assigned to group 1, the second name to group 2, the third name to group 3 and the fourth name to group 4. The procedure continued until the last name in the bag was picked.

The 1st group was recognized as the control group while the 2nd, 3rd and 4th groups were experimental groups. Ten participants were assigned to each of the experimental groups and nine participants were assigned to the control group. Two attritions were recorded and a total number of thirty-seven participants completed the study. The Quadriplegia Index of Function–Short Form (QIF-SF) is a standardized measure. However, content validity test was conducted by three experts in physiotherapy and two experts in exercise physiology. The QIF-SF has high correlation with QIF: Correlation (r) = 0.987 (Total), 0.722-0.879 (Items), Correlation (ρ) = 0.978 (Total) and 0.700-0.845 (Items). The measure equally has high internal consistency: $\alpha = 0.89$ (Marino RJ, et al. [12]). In addition, the measure has a very good responsiveness (Spooren AI, et al. [13]). Ethical approval was sought and obtained from the Ethics and Research Committee of the University of Benin Teaching Hospital, Edo State, Nigeria (ADM/E 22/A/VOL.VII/148273).

The nature, purpose and procedure of the study were explained to the participants in detail. Written informed consent

was obtained from the prospective participants. The QIF-SF was employed to determine the functional independence of the participants at the baseline and the end of the eight (8) weeks of cryokinetics programmes. The QIF-SF was administered face to face by the researchers. A final score ranging from 0 to 24, with 24 indicating the maximum level of functional independence possible was derived. The total score (0-24) is the sum of all item scores. Higher scores indicate greater independence. The participants in the control group received conventional daily treatment protocols (usual treatment protocols), the participants in the experimental group 1 received usual treatment protocols plus ST programmes, the participants in the experimental group 2 received usual treatment protocols plus cryotherapy, while the participants in the experimental group 3 received usual treatment protocols plus cryokinetics.

The conventional daily treatment protocols were administered on Mondays, Tuesdays, Wednesdays, Thursdays and Fridays between 9am to 12pm. The intervention protocols were administered on Mondays, Wednesdays and Fridays between 2pm to 4pm. All the intervention protocols were administered for eight (8) weeks. The ST programmes was an adaptation of (Kwak, et al. [14]) experimental protocol. The protocol is illustrated in (Tables 1 & 2). The ST programmes (Tables 1 & 2) were carefully designed to strengthen the key muscles of the upper and lower limbs of the participants while in supine lying at a frequency of 3 times a week (Monday, Wednesday and Friday). Each day's workout commenced with stretching and ROM exercise to warm up the joints and prepare the body for the resistance training. These minimized the risk of body discomfort or damage and, enhance the benefit of the training. The resistance training was carried out for 15 minutes per session for each of the upper and lower extremity.

Table 1: Elastic-Band Resistance Exercise Programmes for Upper Extremities.

Warm-up exercise	**Stretching** **ROM Exercise**	**3 minutes**
Resistance exercise	Wrist flexion (5a × 1.5b) Wrist extension (5a × 1.5b) + resting time (1b) Elbow flexion (5a × 1.5b) Elbow extension (5a × 1.5b) + resting time (1b) Shoulder flexion (5a × 1.5b) Shoulder adduction (5a × 1.5b) + resting time (1b) Shoulder abduction (5a × 1.5b)	15 minutes, 3 times/week (8 weeks)
Warm-down exercise	Soft tissue mobilization Deep breathing exercise	2 minutes

Note:

a) Times,

b) Minutes

Table 2: Elastic-Band Resistance Exercise Programs for Lower Extremities.

Warm-up Exercise	**Stretching** **ROM Exercise**	**3 minutes**

Resistance exercise	Ankle flexion (5a × 1.5b) Ankle extension (5a × 1.5b) + resting time (1b) Knee flexion (5a × 1.5b) Knee extension (5a × 1.5b) + resting time (1b) Hip flexion (5a × 1.5b) Hip adduction (5a × 1.5b) + resting time (1b) Hip abduction (5a × 1.5b)	15 minutes, 3 times/week (8 weeks)
Warm-down exercise	Soft tissue mobilization Deep breathing exercise	2 minutes

Note:

a) Times,

b) Minutes

Each session comprised of one set of 5 repetitions for each upper and lower limbs' joints including wrist flexion and extension, elbow flexion and extension, shoulder flexion and extension, shoulder adduction and abduction, ankle dorsiflexion, knee extension as well as hip flexion. Each of these movements was performed against the elastic thera band for 1.5 minutes with 1-minute rest between the joints. The training was based on the recommendation of gradual ST for adults American College of Sports Medicine position stand [15]. The yellow thera band was used in the first 4 weeks of the training. The training was progressed with the use of green thera band for the last four weeks. The cryotherapy programmes were an adaptation of (Hopkins JT, et al. [16]) experimental protocol. It involves 30 minutes' application of an ice bag (20.3×40.6 cm) filled-up with 1.5 liters of flaked ice with an elastic bandage each at the wrist, elbow, shoulder joints of the upper extremity and; ankle, knee and, hip joints of the lower extremity.

The cryotherapy was targeted to enhance muscular strengths and joints flexibility of the right and left upper and lower extremities. After the researchers' hands were washed, an ice bag (20.3×40.6 cm) filled-up with 1.5 liter of flaked ice was applied with an elastic bandage each at the wrist, elbow, shoulder, ankle, knee and hip joints of the right and left upper and lower limbs. Waterproof material was kept under each joint (area) and the area was checked after ice application for frostbite. The flaked ice was applied on each joints of the right and left upper and lower limbs for 2.5 minutes. In general, the ice bag was applied for 30 minutes and the areas was cleaned with a dry towel. The participants were made comfortable and then the researchers' hands were washed. This procedure was carried out 3 times a week (Monday, Wednesday and Friday). Moreover, the cryokinetics is the combination of the cryotherapy and the ST programmes. Here, the participants underwent cryotherapy with the ST programmes following.

Furthermore, the daily conventional treatment comprised of manual therapy of cardiopulmonary, passive joints and soft tissue mobilization protocols and pain management procedures. These interventions were carried out for a maximum of 30 minutes. An inferential statistic of one-way analysis of variance (one-way ANOVA) was used to analyze the differences in the functional independence of participants with SCI exposed and not exposed to cryokinetics. The Holm's Sequential Bonferroni Correction post hoc test was used in the case of significant main or interaction effects of the test variable. Statistical significance was accepted for p-value of <0.05. All the analyses were performed with the use of Statistical Package for the Social Sciences (SPSS) version 23.0. The one-way ANOVA conducted to determine the significance of the difference in the functional independence of participants with SCI exposed and not exposed to cryotherapy is presented in (Table 3).

Table 3: Analysis of Variance (ANOVA) Showing Difference in the Functional Independence of the Participants.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	689.048	7	98.435	7.287	0
Within Groups	891.506	66	13.508		
Total	1580.554	73			

Note: df-degree of freedom, F- the ratio of sample variance and Sig.-the two-tailed p-value associated with the null that the groups have the same variance.

Table 4: Holm's Sequential Bonferroni Correction Post-Hoc Comparisons of Mean Difference for Functional Independence of the Participants.

(I) ANOVA	(J) ANOVA	Mean Difference (I-J)	Std. Error	Sig.
Pre ST	Pre CT	-.67778	1.68867	1.000
	Pre CK	-.07778	1.68867	1.000
	Pre Control	-1.40278	1.78586	1.000
	Post ST	-7.44444*	1.73254	.002
	Post CT	-5.47778	1.68867	.052
	Post CK	-7.47778*	1.68867	.001
	Post Control	-1.90278	1.78586	1.000
Pre CT	Pre ST	.67778	1.68867	1.000
	Pre CK	.60000	1.64363	1.000
	Pre Control	-.72500	1.74334	1.000
	Post ST	-6.76667*	1.68867	.004
	Post CT	-4.80000	1.64363	.134
	Post CK	-6.80000*	1.64363	.003
	Post Control	-1.22500	1.74334	1.000
Pre CK	Pre ST	.07778	1.68867	1.000
	Pre CT	-.60000	1.64363	1.000
	Pre Control	-1.32500	1.74334	1.000
	Post ST	-7.36667*	1.68867	.001
	Post CT	-5.40000*	1.64363	.046
	Post CK	-7.40000*	1.64363	.001
	Post Control	-1.82500	1.74334	1.000
Pre Control	Pre ST	1.40278	1.78586	1.000
	Pre CT	.72500	1.74334	1.000
	Pre CK	1.32500	1.74334	1.000
	Post ST	-6.04167*	1.78586	.034
	Post CT	-4.07500	1.74334	.629
	Post CK	-6.07500*	1.74334	.025
	Post Control	-.50000	1.83764	1.000

Post ST	Pre ST	7.44444*	1.73254	.002
	Pre CT	6.76667*	1.68867	.004
	Pre CK	7.36667*	1.68867	.001
	Pre Control	6.04167*	1.78586	.034
	Post CT	1.96667	1.68867	1.000
	Post CK	-.03333	1.68867	1.000
	Post Control	5.54167	1.78586	.079
Post CT	Pre ST	5.47778	1.68867	.052
	Pre CT	4.80000	1.64363	.134
	Pre CK	5.40000*	1.64363	.046
	Pre Control	4.07500	1.74334	.629
	Post ST	-1.96667	1.68867	1.000
	Post CK	-2.00000	1.64363	1.000
	Post Control	3.57500	1.74334	1.000
Post CK	Pre ST	7.47778*	1.68867	.001
	Pre CT	6.80000*	1.64363	.003
	Pre CK	7.40000*	1.64363	.001
	Pre Control	6.07500*	1.74334	.025
	Post ST	.03333	1.68867	1.000
	Post CT	2.00000	1.64363	1.000
	Post Control	5.57500	1.74334	.060
Post Control	Pre ST	1.90278	1.78586	1.000
	Pre CT	1.22500	1.74334	1.000
	Pre CK	1.82500	1.74334	1.000
	Pre-Control	.50000	1.83764	1.000
	Post ST	-5.54167	1.78586	.079
	Post CT	-3.57500	1.74334	1.000
	Post CK	-5.57500	1.74334	.060

Note: ST-strength training, CT-cryotherapy, CK-cryokinetic

The F-value of 7.287 with 7 and 73 degree of freedom was observed to be statistically significant at 0.05 ($p<0.05$). This implies that the cryokinetics had substantial effect on the functional independence of the participants. However, this difference necessitated the conduct of post-hoc test to identify where the difference lies. (Table 4) shows the post-hoc test results of the mean differences in functional independence of the participants. All the pair wise of mean difference were found to be statistically insignificant ($p>0.05$) except pre ST versus post ST (-7.44444*), pre ST versus post CK (-7.47778*), pre CT versus post ST (-6.76667*), pre CT versus post CK (-6.80000*), pre CK versus post ST (-7.36667*), pre CK versus post CT (-5.40000*), pre CK versus post CK (-7.40000*), pre Control versus post ST (-6.04167*), pre Control versus post CK (-6.07500*), post ST versus pre ST (7.44444*), post ST versus pre CT (6.76667*), post ST versus pre CK (7.36667*), post ST versus pre Control (6.04167*), post CT versus pre CK (5.40000*), post CK versus pre ST (7.47778*), post CK versus pre CT (6.80000*), post CK versus pre CK (7.40000*) and post CK versus pre Control (6.07500) as reflected in (Table 4). This implies that the entire pair wise mean had variation. Thus, the ST and CT individually had no substantial influence on the functional independence of the participants. However, only cryokinetics (CK) had substantial influence on the functional independence of the participants.

Discussion

The results of the one-way ANOVA on the effectiveness of ST on the functional independence of the participants has demonstrated that ST as a standalone treatment cannot substantially improve functional independence of the participants' with SCI. However, when combined with cryotherapy, there was significant improvements in clinical outcomes. The findings of this study is completely in contrast with previous studies. Whitley [17], Halil et al. (2017), (Xiao, et al. [2]) and Heydar et al. (2014) have all concluded

that eccentric resistance training served as a stimulus in improving functional independence among individuals with incomplete SCI. These authors contrasting findings could be as a result of differences in the study methods such as subject characteristics, differences in measuring instruments of functional independence, severity of SCI and time of application of the treatment protocols. Furthermore, in this present study adequate muscular strength and joints flexibility, which are strong determinants of functional independence in SCI patients did not improve with cryotherapy alone.

The implication is that using ST programmes as standalone treatment, was responsible for the lack of improvement recorded in the functional independence of the participants in this study. Likewise, hand function which is said to be directly related to functional independence in mobility, basic and instrumental activities of daily living was not enhanced by the ST programmes in the present study. Activities involving the hand also include pivot transfer when using a wheelchair, dressing and bathing, therefore any limitation to these functions would have not only physical impact on patients with SCI, but also psychosocial issues. Furthermore, the inability of these patients to pick up a glass with one hand, type, light a match, do and undo a button will lead to lack of functional independence, self-dignity and self-efficacy. The finding of the post hoc analysis showed that cryotherapy as a standalone treatment did not improve functional independence of SCI patients in this study, but when combined with ST there was significant improvements in clinical outcomes. This was confirmed by the results of the post hoc test following ANOVA.

This result compares favourably with (Kaur, et al. [18]), who confirmed that structured rehabilitation programmes including cryotherapy, stretching and strengthening exercise protocols were effective in optimizing functional independence such as transfers, grip strength, and joints flexibility of patients with tetraplegia following SCI. Other improvements were increased muscular strength, endurance, and gait parameters. However, the (Kaur, et al. [18]), findings were from a single case study, and this could limit its generalization. Notwithstanding, a case study can add context and insight, providing depth to the arguments that already exist, as well as serve as a motivation for further robust studies such as randomised controlled trial (Aveyard [19]). The findings of this present study is consistent with (Robert, et al. [20]) study, who in a literature review involving 20 patients with SCI, found that cryotherapy in combination with surgical decompression, glucocorticoid administration optimized functional independence of the patients.

The implication is that either cryotherapy or ST programmes would not be recommended as a standalone treatment for SCI patients. Some of the shortcomings of the study are the small sample size and lack of proper randomization of participants. Therefore, future studies should include large scale properly randomised controlled trials. Future studies should also consider the experiences of SCI patients receiving cryokinetics in relation to psychosocial factors.

Conclusion

This study has demonstrated that cryokinetics used as an adjunct with standard care can significantly improve the functional independence of patients with SCI. It is therefore recommended that cryokinetics combined with standard treatment protocol should be used for patients with SCI.

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Contributors

AIH conceived the study. AIH, EIA, SO, GEA, SMA and CO provided additional important intellectual and substantial scientific input to all drafts of the study. CO managed all redrafts of the manuscript. AIH is guarantor for the study.

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Competing interests

The authors have declared that no competing interests exist.

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