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RESEARCH ARTICLE

Effectiveness of Cryokinetics on Muscular Strength of Individuals with Spinal Cord Injury

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Abstract

Background: A spinal cord injury (SCI) does not need to be a death sentence. The slant that little can be done to enhance motor function following SCI seems conceptually and empirically part of the past, not the present. This study investigated the effectiveness of cryokinetics on the muscular strength of the upper and lower extremities of participants with spinal cord injuries.

Methods: The present study had an experimental design. Thirty-nine patients with upper spinal cord injuries participated in the present study. The Medical Research Council 6-level scheme was adopted as the scoring scale for muscular strengths. The adapted intervention protocols were designed and applied to improve the muscular strengths of the participants. The upper and lower limbs' muscular strengths of the participants were measured before and after they were subjected to an 8-week cryokinetic study, respectively. Inferential statistics with multiple analyses of variance were used to analyse the data. Statistical significance was retained for a p-value of < 0.05.

Results: The results of this present study showed that the strength training and cryotherapy programmes separately displayed insignificant (p > 0.05) effects on the muscular strengths of the upper and lower extremities of the participants. However, cryokinetics showed significant (p < 0.05) effects on the upper and lower limbs' muscular strengths of participants with upper spinal cord injuries.

Conclusion: It was therefore brought to the conclusion that the strength training programmes and cryotherapy separately cannot substantially influence the muscular strength of the upper and lower limbs of individuals with upper spinal cord injuries, whereas cryokinetics can significantly optimise the muscle strength of this population. Thus, cryokinetics is a great intervention protocol for optimising the muscular strength of people with upper spinal cord injuries. It was therefore recommended that cryokinetics be considered a keystone in the management of individuals with upper spinal cord injuries.

Keywords

Cryokinetics, Muscular strength, Spinal cord injury

Introduction

A spinal cord injury (SCI) does not need to be a death sentence. The slant that little can be done to enhance motor function following SCI seems conceptually and empirically part of the past, not the present. However, SCI requires an efficient and quick response through proper medical rehabilitation protocols [1]. The treatment of SCI is the most challenging of all spinal injuries, and there is still no consensus on the best method of care. If the loss of motor function following SCI is deleterious both to health and functional independence, then what intervention can medical and exercise experts offer to improve the condition of patients with SCI? Cryotherapy can be combined with rehabilitative exercise to decrease pain and enhance muscle function. Cryokinetics is the use of cold treatments before exercise [2]. The combination of treatment variables, such as cryokinetics, for individuals with SCI could have a significant effect on motor recovery.

The use of cryokinetics for patients with SCI depends on the injury site, type, and severity of the injury. The injured body part is numbed, and the individual is instructed to perform various progressive exercises [3]. Cryotherapy, strength training (ST), and a combination

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of the two (cryokinetics) were seen as rehabilitative intervention protocols for SCI in the literature. Nevertheless, few studies have been conducted on the efficacy of some rehabilitation protocols, including ST and cryotherapy, on some of the parameters of motor functions, especially muscle strength, in patients with SCI, with conflicting results. Findings from the literature remain inconclusive as regards the efficacy of cryotherapy and ST employed separately on the muscular strength of people living with SCI. It seems necessary, thus, to determine the effectiveness of cryokinetics on the muscle strength of subjects with SCI. Would there be any difference in the muscle strengths of the upper and lower limbs of individuals with SCI exposed and not exposed to cryokinetics?

Methods

The pretest-posttest control group experimental design was adopted in this study. The study population included 60 participants with upper SCI who were admitted to 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 to four different groups. The first group was recognised as the control group, while the second, third, and fourth 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 of 37 participants completed the study. Ethical approval was sought and obtained from the Ethics and Research Committee of the University of Benin Teaching Hospital, Edo State, Nigeria (ADM/E22/A/VOL.VII/148273).

Manual muscle testing (MMT) was used to measure muscle strengths in the present study. The magnitude to which the participants were able to resist the researcher's force was recorded. The Medical Research Council (MRC) (1976) 6-level scheme was adopted as the scoring scale for MMT. Muscular strengths were measured with the MRC grading as highlighted: 0 = no contraction; 1 = a flicker of contraction; 2 = slight power, enough to move the joint through gravity eliminated; 3 = power sufficient to move the joint against gravity; 4 = power to move the joint against gravity with additional resistance; 5 = normal power. Each group of muscles in the upper and lower limbs was measured bilaterally with MMT.

The sum of all maximum scores possible in each of the key muscles in the right and left upper limbs is 50. Likewise, the sum of all maximum scores possible in each of the key muscles in the right and left lower limbs is 50. The scores from each of the key muscles in the right and left upper limbs were summed up together to arrive at a value representing the total muscle strength of the upper limbs. Equally, the scores from each of the key muscles in the right and left lower limbs were summed up together to arrive at a value representing the total muscular strength of the lower limbs. Higher scores indicate greater muscle strength.

One of the researcher's hands palpates the muscle or tendon of the group of muscles to be measured for contraction and also applies resistance, while the other hand stabilises the limb of the muscle group being tested to ensure the right test position. The participant is expected to exert a great deal of effort to ensure maximum contraction. If a participant does not comprehend the instructions or cannot apply greater effort, the test is repeated. In the present study, the strength of each of the key muscles in both the upper and lower limbs was tested and measured separately. Each key muscle function was tested in an anterior-posterior sequence with standard supine positioning, while the muscles being tested were stabilized. The five major key muscles in the upper limbs (elbow flexors, wrist extensors, elbow extensors, finger flexors (distal phalanx of the middle finger), finger abductors (little finger), and the five major key muscles in the lower limbs (hip flexors, knee extensors, ankle dorsiflexors, big toe extensors, and ankle plantar flexors) based on the standard neurological classification of SCI were tested and measured.

The participants in the control group received conventional daily treatment protocols (usual treatment protocols); the participants in experimental group 1 received usual treatment protocols plus ST programmes; the participants in experimental group 2 received usual treatment protocols plus cryotherapy; and the participants in experimental group 3 received usual treatment protocols plus cryokinetics. The conventional daily treatment protocols were administered on Mondays, Tuesdays, Wednesdays, Thursdays, and Fridays between 9 a.m. and 12 p.m. The intervention protocols were administered on Mondays, Wednesdays, and Fridays between 2 p.m. and 4 p.m. All the intervention protocols were administered for 8 weeks. The ST programmes were an adaptation of the Kwak [4] experimental protocol.

The ST is an exercise training programme in which the participants were exposed to repeat periods of work interspersed with rest periods. The ST programmes (Table 1 and Table 2) were carefully designed to strengthen the key muscles of the upper and lower limbs of the subjects at a frequency of three times a week (Monday, Wednesday, and Friday). Each day's workout commenced with stretching and ROM exercises to warm up the joints and prepare the body for the resistance training. These minimised the risk of body discomfort or damage and enhanced the benefit

Table 1: Elastic-band resistance exercise programmes for upper extremities.

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

^{a}times; ^{b}minutes

Table 2: Elastic-band resistance exercise programmes for lower extremities.

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

^{a}times; ^{b}minutes

of the training. The resistance training was carried out for 15 minutes per session for each of the upper and lower extremities. Each session consisted of one set of five repetitions for each upper and lower limb's joints. Each of these movements was performed against the elastic thera band for 1.5 minutes with a 1-minute rest between the joints. The yellow thera band was used in the first 4 weeks of the training. The training progressed with the use of a green thera band for the last four weeks.

The cryotherapy was targeted to enhance the muscular strengths and joint flexibility of the right and left upper and lower extremities. After the researcher's hands were washed, an ice bag (20.3 × 40.6 cm) filled with 1.5 litres 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 to each joint 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 were cleaned with a dry towel. The participants were made comfortable, and then the researcher's hands were washed. This procedure was carried out three times a week (Monday, Wednesday, and Friday). The cryokinetics are the combination of cryotherapy and ST programmes. Here, the subjects underwent cryotherapy with the ST programmes.

Furthermore, the daily treatment is comprised of manual therapy, cardiopulmonary, passive joint mobilisation, soft tissue mobilisation protocols, and pain management procedures. These interventions were carried out for a maximum of 30 minutes. An inferential statistic of one-way MANOVA was adopted to analyse the difference in the muscular strengths of the upper and lower limbs of subjects 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 a 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 MANOVA conducted to determine the significance of the difference in the muscular strength of participants with SCI exposed and not exposed to cryokinetics is presented in Table 3.

Results

From Table 3, the multivariate test showed that there

Table 3: One-way MANOVA showing the main and interaction effects of cryokinetics on muscle strengths of upper and lower extremities of the subjects.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	ULMS	932.523[a]	7	133.218	30.063	0.000	0.761
	LLMS	1004.645[b]	7	143.521	27.565	0.000	0.745
Intercept	ULMS	84291.382	1	84291.382	19021.942	0.000	0.997
	LLMS	91879.474	1	91879.474	17646.563	0.000	0.996
MANOVA	ULMS	932.523	7	133.218	30.063	0.000	0.761
	LLMS	1004.645	7	143.521	27.565	0.000	0.745
Error	ULMS	292.464	66	4.431			
	LLMS	343.639	66	5.207			
Total	ULMS	86837.000	74				
	LLMS	94323.000	74				
Corrected Total	ULMS	1224.986	73				
	LLMS	1348.284	73				
[a]R Squared = 0.761 (Adjusted R Squared = 0.736)							
[b]R Squared = 0.745 (Adjusted R Squared = 0.718)							

ULMS: Upper Limb Muscle Strength; LLMS: Lower Limb Muscle Strength

Table 4: Holm's sequential bonferroni correction post-hoc comparisons of mean difference for muscle strengths of upper and lower extremities of the subjects.

Dependent Variable	(I) MANOVA	(J) MANOVA	Mean Difference (I-J)	Std. Error	Sig.
ULMS	Pre ST	Pre CT	-0.9111	0.96721	1.000
		Pre CK	0.2889	0.96721	1.000
		Pre Control	0.1389	1.02287	1.000
		Post ST	-2.4444	0.99233	0.459
		Post CT	-1.8111	0.96721	1.000
		Post CK	-10.8111*	0.96721	< 0.001
		Post Control	-0.4861	1.02287	1.000
	Pre CT	Pre CK	1.2	0.94141	1.000
		Pre Control	1.05	0.99852	1.000
		Post ST	-1.5333	0.96721	1.000
		Post CT	-0.9	0.94141	1.000
		Post CK	-9.9000*	0.94141	< 0.001
		Post Control	0.425	0.99852	1.000
	Pre CK	Pre Control	-0.15	0.99852	1.000
		Post ST	-2.7333	0.96721	0. 174
		Post CT	-2.1	0.94141	0.815
		Post CK	-11.1000*	0.94141	< 0.001
		Post Control	-0.775	0.99852	1.000
	Pre Control	Post ST	-2.5833	1.02287	0.391
		Post CT	-1.95	0.99852	1.000
		Post CK	-10.9500*	0.99852	< 0.001
		Post Control	-0.625	1.05253	1.000
	Post ST	Post CT	0.6333	0.96721	1.000
		Post CK	-8.3667*	0.96721	< 0.001
		Post Control	1.9583	1.02287	1.000
	Post CT	Post CK	-9.0000*	0.94141	< 0.001
		Post Control	1.325	0.99852	1.000
	Post CK	Post Control	10.3250*	0.99852	< 0.001

LLMS	Pre ST	Pre CT	0.9889	1.05829	1.000
		Pre CK	1.8889	1.05829	1.000
		Pre Control	0.7639	1.1192	1.000
		Post ST	-6.1111*	1.08578	< 0.001
		Post CT	-0.6111	1.05829	1.000
		Post CK	-9.4111*	1.05829	< 0.001
		Post Control	0.0139	1.1192	1.000
	Pre CT	Pre CK	0.9	1.03006	1.000
		Pre Control	-0.225	1.09255	1.000
		Post ST	-7.1000*	1.05829	< 0.001
		Post CT	-1.6	1.03006	1.000
		Post CK	-10.4000*	1.03006	< 0.001
		Post Control	-0.975	1.09255	1.000
	Pre CK	Pre Control	-1.125	1.09255	1.000
		Post ST	-8.0000*	1.05829	< 0.001
		Post CT	-2.5	1.03006	0.503
		Post CK	-11.3000*	1.03006	< 0.001
		Post Control	-1.875	1.09255	1.000
	Pre Control	Post ST	-6.8750*	1.000.1192	< 0.001
		Post CT	-1.000.375	1.000.09255	1.000
		Post CK	-10.1750*	1.000.09255	< 0.001
		Post Control	-0.75	1.000.15164	1.000
	Post ST	Post CT	5.5000*	1.000.05829	< 0.001
		Post CK	-3.3	1.000.05829	0.075
		Post Control	6.1250*	1.000.1192	< 0.001
	Post CT	Post CK	-8.8000*	1.000.03006	< 0.001
		Post Control	0.625	1.000.09255	1.000
	Post CK	Post Control	9.4250*	1.000.09255	< 0.001

ST: Strength Training; CT: Cryotherapy; CK: Cryokinetics; ULMS: Upper Limb Muscle Strength; LLMS: Lower Limb Muscle Strength

was a statistically significant ($p < 0.05$) difference in the muscular strengths of the upper and lower extremities of the participants exposed and not exposed to cryokinetics. This, however, necessitated probing into the post-hoc test to investigate the interaction effects of the independent intervention groups on the muscle strengths of the upper and lower extremities of the participants. The results of these interactions are summarised in Table 4.

Holm's Sequential Bonferroni Correction Post-Hoc Test was carried out to determine the interaction effects of the independent intervention groups on the muscle strengths of the upper and lower extremities of the participants. For the upper extremity muscle strength, all the pairwise mean differences were found to be statistically insignificant ($p > 0.05$) except pre-ST versus post-CK (-10.8111*), pre-CT versus post-CK (-9.9000*), pre-CK versus post-CK (-11.1000*), pre-Control versus post-CK (-10.9500*), post ST versus post-CK (-8.3667*), post CT versus post-CK (-9.0000*), post-CK versus post-Control (10.3250*). Likewise, for the lower extremity muscle strength, pre ST versus post-ST (-6.1111*), pre-ST versus post-CK (-9.4111*), pre-CT versus post-ST (-7.1000*), pre-CT versus post-CK (-10.4000*), pre-CK versus post-ST (-8.0000*), pre-CK versus post-CK (-11.3000*), pre-Control versus post-ST (-6.8750*), pre-Control versus post-CK (-10.1750*), post-ST versus post-CT (5.5000*), post-ST versus post Control (6.1250*), post-CT versus post-ST (-5.5000*), post-CT versus post-CK (-8.8000*), post-CK versus post Control (9.4250*) and post Control versus post-ST (-6.1250*) as shown in Table 4. This implies that the entire pair-wise mean had variation. Therefore, the ST and CT individually did not influence the upper extremity muscle strength of the subjects but ST alone significantly influenced the lower extremity muscle strength of the subjects. However, cryokinetics (CK) had a substantial influence on the muscle strengths of the upper and lower extremities of the participants.

Discussion

The results of the MANOVA on the effectiveness of ST on the muscular strengths of the participants indicated that the ST administered had no considerable effect on the participants' muscular strengths. This finding is in disagreement with Flavia, et al. [5]; Serra-Ano, et al. [6]; Bye, et al. [7]; Harvey, et al. [8] submissions that the ST programme had a significant effect on the muscular strength of subjects with SCI. These contrasting findings could be a result of differences in the study methods, such as participants' characteristics of being black or from a developing country like Nigeria, differences in measuring instruments of muscular strength, and so on. Moreover, the inability of the ST programme to combat a decrease in the number of mitochondria in the muscle cells, a reduction in glycogen synthesis, and an increase in the amount of circulating systemic inflammatory cytokines, all of which have a negative effect on the muscular strength of participants with SCI, may be responsible for the insignificant increase in muscular strength observed in these individuals. Similarly, it's possible that the eight-week ST programme could not result in an increase in the cross-sectional area of muscle fibres, a decrease in type IIB fibres, or a higher proportion of type IIA fibres in the muscle. In other words, it's possible that a shift towards a greater oxidative capacity and a slower rate of contraction was not achieved in order to maintain muscle strength.

Equally, on the effectiveness of cryotherapy on the muscular strengths of the participants, the results revealed that the cryotherapy administered had no substantial effect on the participants' muscular strengths. This finding did not enjoy the support of Jokonya [9] work on two cases of patients with complete SCI who developed severe, medically intractable muscle spasms, and when cryotherapy was applied to both lower limbs, significant improvement was observed. The authors thus, found and reported significant improvement in muscular strength following cryotherapy and other treatment protocols. The above empirical study is related to the study at hand because the two studies tried to establish the effectiveness of cryotherapy and other therapeutic modalities on the muscle strength of participants with SCI. However, discrepancies between the two studies might have been the result of variations in the type of SCI studied, the number of participants investigated, the type of study, and the like.

Cryokinetics was observed to have a significant influence on muscle strengths in the present study. The post hoc analysis clearly showed a statistically significant effect of cryokinetics on the muscle strength of the participants as compared with ST and cryotherapy separately. This may not be unexpected because the result could be a reflection of the benefit of combined intervention protocols such as cryokinetics to address muscular weakness following SCI. This may, in part, be attributed to the quality of cryokinetics programmes. This finding can be compared conditionally to minimal available data because of differences in the chosen participants' characteristics, training programmes, time of application, scoring methods, and procedures in other studies.

Conclusion

It can be concluded from this study that ST and cryotherapy separately cannot influence the motor functions of the upper and lower extremities of participants with upper SCI. However, cryokinetics can substantially influence the motor functions of the upper and lower extremities of people with upper SCI. The study therefore revealed that cryokinetics is a good training modality for improving the upper and lower extremities' motor functions in people with upper SCI.

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Contributors

AIH conceived the study. AIH, Obinna, Kayode provided additional important intellectual and substantial scientific input to all drafts of the study. 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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