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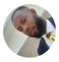
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ORIGINAL SCIENTIFIC PAPER

Effects of Cryokinetics on Hand Function of Patients with Spinal Cord Injury

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Abstract

This study investigated the effects of cryokinetics on hand function of subjects with spinal cord injury. The present study has an experimental design. Thirty-nine subjects with upper spinal cord injury were included. Handgrip and pinch strength were measured using electronic hand dynamometer (in kg) and mechanical pinch gauge (in kg) respectively prior to and following an 8-week cryokinetics. The amount of handgrip and pinch strength of both hands generated by each participant was used as a quantitative measurement of the development of hand function. Inferential statistics of multiple analysis of variance was used to analyze the data. Statistical significance was retained for p value <0.05. The results of this study revealed that the strength training and the cryotherapy programmes separately had insignificant ($p>0.05$) effects on the hand function of the subjects. However, cryokinetics had significant ($p<0.05$) effects on the hand function of subjects with upper spinal cord injury. It was therefore concluded that the strength training programmes and cryotherapy individually cannot substantially influence hand function of subjects with upper spinal cord injury whereas, cryokinetics can substantially enhance hand function of the participants. Thus, cryokinetics is an excellent intervention protocol for optimizing hand function of subjects with upper spinal cord injury. It was therefore recommended that cryokinetics should be regarded as keystone in the management of subjects with upper spinal cord injury.

Keywords: *Cryokinetics, Hand function, Spinal cord injury*

Introduction

Spinal cord injury (SCI) could cause alterations in the structure and functions of spinal cord that might result to motor dysfunctions such as difficulty in walking and the use of hands, thereby, leading to restriction in daily activities (Draulans, Kiekens, Roels, & Peers, 2011). Rehabilitation medicine emphasizes strengthening exercises and functional training for self-adequacy and mobility. This practice may have overlooked some other physical rehabilitation protocols such as cryotherapy, which might have some health benefits. Thus far, evaluation of hand function following cryotherapy is hardly ever evident in the rehabilitation programme, while assessment of grip strength and hand function after strength training (ST) is carefully documented (Hammed, Agbonlahor, Ogbouma, Arainru, Adodo, & Ogbeivor, 2022). Individuals with paralysis of upper and lower extremities (tetraplegia) recognize restoration of hand and arm function as indispensable for functional recovery; whereas individuals with paralysis of the lower extremities (paraplegia) mention walking as their prime concern (French, Anderson-Erisman & Sutter, 2010). Thus, the functions of the upper extremity are mostly affiliated with the performance of daily activities and gregarious participation. The upper extremities allow for complex task accomplishment in exploration, prehension, 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 & Eng, 2007). For optimum productivity, ample muscle power is required while decline in muscle strength is a prognosticator of physical limitations (Hammed & Adodo, 2017). The functions of the upper extremity can also be determined by the joint movement, stability, and strength. Furthermore, joint flexibility is very crucial to general wellbeing and functionality

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(Ribeiro, Campos-Filho, Avelar, dos-Santos, Júnior, Aguiara, … & Cyrino, 2017). The shortness and tightness of muscles as a result of disuse could cause an increase in injury and strains as well as reduction in joint flexibility. Grip and pinch strengths have been shown to have significant influence on the function of the upper extremity (Kim, 2016).

Cryokinetics is a technique in which cold is applied for few minutes, and then followed by strength exercise (Knight & Draper, 2013). It remains untold, how frequent, or to what extent, ST and cryotherapy are capable of enhancing the hand function of individuals after SCI. The effects of ST on hand function after SCI have been controversial in previous evidence, while the effects of cryotherapy are poorly documented. Therefore, this study was designed to investigate the use of cryokinetics to challenge hand dysfunctions associated with SCI. The objective is to assess if there are differences in the hand function of subjects 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 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. A simple random sampling technique of balloting with replacement was then used to assign the participants into four different groups. 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. 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 subjects in the control group received conventional daily treatment protocols (usual treatment protocols), the subjects in the experimental group 1 received usual treatment protocols plus ST programmes, the subjects in the experimental group 2 received usual treatment protocols plus cryotherapy while the subjects 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 8-weeks. The ST programme protocol was adapted from Kwak, Kim and Lee (2016). Handgrip and pinch strength were measured using electronic hand dynamometer (in kg) and mechanical pinch gauge (MPG) (in kg) respectively, prior to, and following an 8-week intervention.

Handgrip Strength Measurement

The American Society of Hand Therapists guidelines (Schreuders, Roebroeck, Goumans, Van-Nieuwenhuijzen, Stijnen & Stam, 2003; Fess, 1992) was followed in the measurement of hand grip strength. The subject lies supine comfortably in postural reduction, with 90° of elbow flexion and the forearm and wrist in a neutral position. The researcher demonstrates to each participant on how to use the device to familiarize the participant with the use of the apparatus and to remove the element of fear. Three maximum power gripping trials were made by each hand of the participant, with three-second contractions and ten-second rest periods between the attempts, and only the best of the three attempts was recorded. No assistance of the hand under test was allowed. The device was adjusted for variant hand sizes and preferences by adjusting the center knob. All readings were recorded in kilograms in the present study.

Pinch Strength Measurement

The guidelines of Schreuders et al. (2003) was followed in the measurements of pinch strength. The MPG was zeroed prior to testing of each pinch with the rotation of the small curled knob on top of the dial indicator in an anticlockwise direction until it rests against the black pointer at the zero marking. A single maximum effort was recorded for key pinch, palmer pinch and tip pinch because muscle fatigue begins with the first concentrated effort. The following test instructions were provided: "you must squeeze the handle as hard as possible keeping both your body and arm in position". All readings were recorded in kilograms in the present study.

Key pinch (lateral pinch)

The subject comfortably lies supine in postural reduction, with the test arm at the side and elbow flexed 90°, palm facing inward, while the MPG gauge is placed between the flexed proximal interphalangeal joint of index finger and thumb. The researcher stood in front of the subject to the side holding the MPG and the subject was asked to hold, squeeze and, release the gauge. That is, subject applied pinch force at the pinch groove while holding the pinch gauge between his/her thumb and index fingers.

Palmer pinch (chuck pinch)

The subject suitably lies supine with the test arm at the side and elbow flexed 90°, palm facing downward. The subject held pinch gauge between thumb and the index and middle fingers. The researcher stood in front of the subject to the side holding the gauge and the subject was asked to hold, squeeze and, release the gauge.

Tip pinch (thumb-index pulp pinch)

The subject suitably lies supine with the test arm at the side and elbow flexed 90°, palm facing downward. The pinch gauge was between thumb and test finger in the absence of interpose of other fingers. The researcher stood in front of the subject to the side holding the MPG and the subject was asked to hold, squeeze and, release the gauge.

Hand Function

This study made use of handgrip strength and pinch strength as an overall quantitative assessment of hand function, extrapolating the works of Weiss and Flatt (1971) and Dickson and Calnan (1972). The magnitude of the handgrip strength and pinch strength (key pinch, palmer pinch and tip pinch) measured in kilograms produced by each participant was summed up and recorded as hand function for each subject as previously done by Schreuders et al. (2003). Higher handgrip and pinch strengths indicate better hand function. The right and left hand function for each subject were recorded and analyzed separately. The best of the three attempts was recorded for the grip strength but a single maximum effort was recorded for pinch strength because muscle fatigue begins with the first concentrated effort.

The ST is an exercise training program in which the subjects were exposed to repeated period of work, interspersed with rest periods. ST program (Tables1) was consisted of exercises to strengthen the key muscles of the upper limbs of the subjects at a frequency of 3 times a week (Monday, Wednesday and Friday). Each day's workout commenced with stretching and range of motion (ROM) exercise to warm up the joints and prepare the body for the resistance training. This procedure minimized the risk of body discomfort or damage and, enhanced the benefit of the training. The resistance training was carried out for 15 minutes per session for each of the upper extremity. Each session comprised of one set of 5 repetitions for each upper limbs' joints. Each of these movements was performed against the elastic theraband for 1.5 minutes with 1-minute rest between the joints. The theraband with lower resistance was used in the first 4 weeks of the training. The training was progressed with the use of theraband with higher resistance for the last four weeks.

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

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

[a]times, [b]minutes

The cryotherapy was targeted to enhance hand function and joints flexibility of upper extremities. After the researcher's 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, and shoulder joints of upper 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 upper limbs for 2.5 minutes. In general, the ice bag was applied for 15 minutes and the area was cleaned with a dry towel. This procedure was carried out 3 times a week (Monday, Wednesday and Friday).

The cryokinetics is the combination of the cryotherapy and the ST program. Here, the subjects underwent the same procedure for cryotherapy as explained previously, and then was followed by the ST program.

Furthermore, the daily treatment for all experimental groups 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.

Statistical analysis

An inferential statistic of one-way MANOVA was adopted to analyze the difference in the hand function 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 p-value <0.05.

Results

Table 2 shows the results of multivariate test. A statistically significant (p<0.05) difference was found in the hand function of the subjects 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 hand function of the subjects. The results of these interactions are presented in Table 3.

Table 2: One-Way MANOVA Showing the Main and Interaction Effects of Cryokinetics on Hand Function of the Subjects

Dependent Variable	F	P value
RHF	5.317	<0.001
LHF	5.634	<0.001
RHF	228.644	<0.001
LHF	238.632	<0.001
RHF	5.317	<0.001
LHF	5.634	<0.001

RHF-right hand function, LHF-left hand function

Table 3 shows the post-hoc test results of the mean differences in hand function of the subjects. For the right hand function, all the pair wise of mean difference were found to be statistically insignificant (p>0.05, data not shown) except pre ST versus post CK (-7.270*), pre CT versus post CK (-6.410*), pre CK versus post CK (-8.210*), pre Control versus post CK (-5.282*), post CT versus post CK (-5.410*), post CK versus pre ST (7.270*), post CK versus pre CT (6.410*), post CK versus pre CK (8.210*), post CK versus pre Control (5.282*) and post CK versus post CT (5.410*). Likewise, for the left hand function, pre ST versus post CK (-7.386*), pre CT versus post CK (-6.600*), pre CK versus post CK (-7.770*), pre Control versus post CK (-5.205*), post CT versus post CK (-5.600*), post CK versus pre ST (7.386*), post CK versus pre CT (6.600*), post CK versus pre CK (7.770*), post CK versus pre Control (5.205*) and post CK versus post CT (5.600*) as reflected in Table 3. This implies that the entire pair wise mean had variation. Therefore, the ST and CT separately had no substantial influence on the hand function of the subjects. However, cryokinetics (CK) had substantial influence on the hand function of the subjects.

Table 3: Holm's Sequential Bonferroni Correction Post-Hoc Comparisons of Mean Difference for the Hand Function of the Subjects

Dependent Variable	(I) MANOVA	(J) MANOVA	Mean Difference (I-J)	P value
RHF	Pre ST	Post CK	-7.270*	<0.001
	Pre CT	Post CK	-6.410*	0.002
	Pre CK	Post CK	-8.210*	<0.001
	Pre control	Post CK	-5.282*	0.042
	Post CT	Post CK	-5.410*	0.017
	Post CK	Pre ST	7.270*	<0.001
	Post CK	Pre CT	6.410*	0.002
	Post CK	Pre CK	8.210*	<0.001
	Post CK	Pre control	5.282*	0.042
	Post CK	Post CT	5.410*	0.017
LHF	Pre ST	Post CK	-7.386*	<0.001
	Pre CT	Post CK	-6.600*	0.001
	Pre CK	Post CK	-7.770*	<0.001
	Pre control	Post CK	-5.205*	0.029
	Post CT	Post CK	-5.600*	0.006
	Post CK	Pre ST	7.386*	0.000
	Post CK	Pre CT	6.600*	0.001
	Post CK	Pre CK	7.770*	0.000
	Post CK	Pre control	5.205*	0.029
	Post CK	Post CT	5.600*	0.006

RHF-right hand function, LHF-left hand function, ST-strength training, CT-cryotherapy, CK-cryokinetics
*Only statistically significant results are presented (P<0.05)

Discussion

The result of the MANOVA on the effect of ST on hand function of the subjects indicated that the ST administered had no considerable effect on the subjects' hand function. This finding is in disagreement with Hammed, Adodo and Agwubike (2018); Agbonlahor and Hammed (2017); Agbonlahor and Hammed (2016); Bacchi, Negri, Targher, Faccioli and Lanza (2013) who found a significant effect of ST on grip strength and hand function in subjects with SCI. This might be due to differences in the methodological design because previous authors did not test for pinch strength in their study. Our results are also opposing the reults of Lisa, Sarah, Leonid, Ya-Seng and Mary (2011) who reported that an 8-week programme of intensive unilateral hand training including ST improves hand function of subjects with SCI. This might be again related to differences in the study methods such as intervention protocols, subject characteristics or variations in measuring instruments, variations in the degree or clinical features of SCI levels and so on. Moreover, the insignificant improvement in hand function found in the present study following ST can be adjudged in two different standpoints. Firstly, poor grip strength as the origin of first episode of poorer hand function. This is because the grip strength shows the strength generated by the contraction of the many arm and hand muscles required in the proper functioning of the hand. Likewise, there is a consensus that grip strength is a predictor of hand function and is mostly employed to determine functional limitation of the hand (Ruprai, Tajpuriya, & Mishra, 2015). Secondly, the insignificant effect of ST programme on the intrinsic and extrinsic muscles of the hand and forearm which enable the hand to function properly might also explain why there was no significant improvement of the hand function in the present study following ST program

Moreover, the results of the MANOVA on the efficacy of CT on hand function of the subjects indicated that the CT administered had no substantial effect on the subjects' hand function. This finding is in line with the study of Bhandari and Parmar (2014). In contrast, the result of the present study disagrees with the studies of Abd El-Maksoud, Sharaf and Rezk-Allah (2011) and Ariela, Priscila, Alderico, Fernanda and Mario (2019) who reported that CT was effective in increasing the patients' palmar grip strength and hand function. However, discrepancies which exist in the present and previous studies include different population, variation in the number of subjects, different intervention protocols and nuances in measuring instruments. Cryokinetics was observed to have significant influence on hand function in this study. The post hoc analysis equally shows that cryokinetics can significantly optimize hand function of subjects with upper SCI as compared with ST and CT separately. Cryokinetics is a technique that combines application of cold pack directly on the joints followed by a strength exercise (Knight & Draper, 2013). ST can cause structural and functional alteration in the cerebral cortex, spinal cord, and skeletal muscles, thereby optimizing neural and muscular function after SCI (Ehrhardt & Morgan, 2005). Furthermore, ST seems to enhance nerve regeneration with functional recovery, to cause corticospinal pathway connectivity, to ensure the functional status of spinal cord neurons, to activate skeletal muscle satellite cells, and to enhance muscle fiber regeneration (Li, Ding, Y.H., Rafols, Lai, McAllister & Ding, 2005). Several studies have reported significant effects of ST on muscle function (Flavia, Katia, Ana, Kesley, Isis, Humberto, Jose, & Maria, 2018; Serra-Ano, Pellicer, Xavier, Jose, Pascual, & Gonalez, 2012; Bye, Harvey, & Gandevia, 2017). Moreover, nerve excitation and contraction of skeletal muscles can be elicited by application of ice directly on the joints, that is, joint cryotherapy (Pietrosimone & Ingersoll, 2009). Thus, the results in our study may be a reflection of the benefit of combined intervention protocols (ST and CT) to bring about better muscle function.

Conclusion

It can be concluded from this study that ST and CT separately cannot influence hand function of subjects with upper SCI. However, cryokinetics (combination of ST and CT) can substantially influence hand function of subjects with upper SCI. The study therefore revealed that cryokinetics is a good training modality for improving hand function of subjects with upper SCI.

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Contributors

AIH conceived the study. OSK, AO, DA and EO 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

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