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PJM and Cryotherapy in a New Approach for Spasticity Management: An Experimental Trial

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ABSTRACT

Background: Spasticity has been proven to affect the quality of life and functional rehabilitation in patients post-stroke. Several studies aimed to investigate ways to reduce muscle tonicity in this population. Peripheral joint mobilization (PJM) as well as cryotherapy can be used effectively to reduce spasticity and enhance the range of motion.
Objectives: This study aimed to investigate the direct effect of cryotherapy, and that of peripheral joint mobilization, on spasticity as a primary outcome and range of motion as a secondary outcome in stroke patients.
Methods: Eighteen participants met the inclusion criteria. Patients with ankle plantarflexor spasticity (n=14), patients with biceps brachii spasticity (n=13), and patients with triceps brachii spasticity (n=10) underwent our interventions on two distinct visits. On the first session, Kaltenborn's PJM was performed, while on the second session ice-massaging technique was applied on the biceps brachii, triceps brachii, and gastrocnemius muscles over the duration of five continuous minutes. The assessment tools used were Modified ashworth scale (MAS) to assess spasticity level and goniometer to evaluate the range of motion (ROM). Statistical tests were performed using SPSS software, Version 23.0.
Results: Cryotherapy and peripheral joint mobilization showed a significant reduction in spasticity of the biceps brachii and triceps brachii muscles ($p < 0.05$), while only cryotherapy had a significant change on gastrocnemius muscle. For ROM, only PJM showed a significant positive change on both active and passive ranges.
Conclusion: Both modalities showed effectiveness in direct reduction of spasticity, hence contributing to a more manageable and practical functional rehabilitation of stroke patients.

KEYWORDS: Cryotherapy, Peripheral Joint Mobilization, Spasticity, Stroke.

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I. INTRODUCTION

According to WHO, stroke was classified as the second leading cause of death and the third leading cause of acquired adult disability at the global level (WHO's Global Health Estimates, 2019). This worldwide position has dramatically affected the Middle Eastern countries, that has seen a significant increase in the incidence rate of stroke in the last decade, exceeding the level seen in some high-income countries (Maya El-Haj et al, 2016)

Although most stroke patients recover to a certain level, long-term disability is a common sequela among these patients (Hankey et al, 2002). A common consequence of stroke is spasticity, with incidence rate ranging from 30% to 80% of stroke survivors (Kuo et al, 2018), characterized by increased in muscle tone that results in greater motor impairment. (Pundik et al, 2019)

According to recent studies, spasticity is more frequently presented in the upper extremities than in the lower extremities (Lundstrom et al, 2010, Urban et al, 2010), with the development of abnormal postural patterns and it has been considered as a major determinant of activity limitations (boyd et al, 2018). It may have an impact on comfort, posture, ease of care, and function. In addition, it may increase the risk of comorbid complications, such as contractures and skin ulcers (Kuo et al, 2018). Lower limb spasticity in particular may affect balance, mobility, and gait, and may also increase the risk of falls and fractures in people who have experienced stroke. Hence, management of increased muscle tone is considered an important goal in post-stroke patient care and rehabilitation. (Boyd et al, 2018, Kuo et al, 2018)

Several approaches to control spasticity have been investigated, including non-pharmacological and pharmacological treatments, and are usually combined in clinical practice, which all aim to avoid complications, increase functional abilities and improve the quality of life, rather than eliminating spasticity. (Kuo et al, 2018, Bethoux, 2015). One of the basis of non-pharmacological management is the application of physical modalities. This latter includes stretching, casting and splints, ultrasound, thermotherapy, vibration and neuro-muscular electrical stimulation (Kuo et al, 2018, Boyd et al, 2018, Bethoux, 2015).

Lately, several studies have discussed the effect of cryotherapy and peripheral joint mobilization in minimizing spasticity. Joint mobilizations are low-amplitude or high-amplitude, low-velocity movements that are in the forms of sustained or oscillatory motions, to the spinal vertebrae or peripheral joints with or without movement. (Md et al, 2015, Kaminski et al, 2007, Netter et al, 2002) It can be used to stimulate neurophysiological effects in order to help treat muscle spasm and reflex muscle guarding, along with associated pain. (Manske et al, 2018, Kaminski et al, 2007)

Cryotherapy can be defined as the use of cold in order to decrease tissue temperature for therapeutic conditions (Garcia et al, 2018, Guimarães et al, 2020). Its main objective is to reduce mioarticular viscoelastic tension and facilitate neuromuscular function in the spastic limb (Guimarães et al, 2020).

Due to the lack of knowledge in the effect of peripheral joint mobilization on spasticity and the deficit of studies supporting the usage of ice massage technique, the purpose of our study is to evaluate and compare the immediate effect of peripheral joint mobilization and cryotherapy (ice massage modality) in reducing spasticity on biceps, triceps and ankle plantar-flexor muscle in stroke patients.

II. MATERIALS AND METHODS

II.1. Experimental Design Overview

This study was a Quasi experimental, pre-test/post-test study, conducted with patients suffering from spasticity after stroke. An extensive literature search was done using mainly the PubMed electronic database, relying mostly on studies above 2010. Participants were recruited from a variety of sources including the Dar Al Ajaza foundation, and private clinics in Beirut. Our team's complied with the health safety measurements against COVID-19 and conducted PCR tests a day before the start of the experiment.

The Study was approved by the ethical Committee of Global University, Beirut. All participants provided written informed consent.

Initial assessment included screening evaluation performed for sample selection according to the inclusion and exclusion criteria. On the same day, a clinical assessment was performed if the participant had met the criteria. Then, the enrolled participants underwent two consecutive interventions with 2 days interval between. According to the results of the initial assessment, the included subjects were distributed into 2 groups: Upper Limb group (n=16) and Lower Limb group (n=14). (Figure 1)

On Day 1, the level of spasticity of the elbow (biceps and triceps) and ankle (plantarflexors) was assessed and scored according to the Modified Ashworth Scale, in addition to the assessment of passive and active range of motion (ROM) of elbow flexion, extension and ankle dorsiflexion and plantarflexion using a goniometer, by a skillful physical therapist. Both assessments were done on the first and second visits, before and immediately after the peripheral joint mobilization and cryotherapy, respectively.

II.2. Participants

The following inclusion criteria were used: Hemi paretic patients due to ischemic or hemorrhagic stroke of any hemispheres, age above 40 years, spasticity on biceps or triceps or on the ankle plantar-flexors muscles, and participants should be conscious, oriented, and cooperative. On the other hand, the following exclusion criteria were used: 1) Peripheral neuropathy or intolerance to the ice cube application, 2) Shoulder subluxation after stroke, 3) ulcers or skin lesions on the area of the intervention application. 4) Presence of any serious cardiovascular or peripheral vascular disease, 5) any other orthopedic or neurological disorder in area of application, or previous joint or muscle injuries. 6) Botulinum toxin application up to six months before the study, 7) presence of bony block on elbow or ankle, 8) any cognitive or communication disabilities and 9) severe pain during the assessment and intervention procedures.

A total group of 21 persons with spasticity following stroke from the different centers were assessed for eligibility. From these subjects, 3 subjects were excluded from the study due to either no spasticity, bony block, or subluxation, and only 18 met the criteria and were enrolled in the study. From the 18 participants, 14 had ankle spasticity and 16 had elbow spasticity (biceps n=13 and triceps n=10)

II.3. Clinical assessment:

In order to characterize the subjects enrolled in this study, a clinical evaluation was carried out, which included 1) collecting personal data, including age, dominant hand and stroke-related information; 2) Modified Ashworth Scale (MAS) to measure the spasticity level, 3) Passive / Active range of motion (ROM) for elbow flexion/extension and ankle dorsiflexion/plantarflexion using a goniometer.

The Primary outcome was the MAS. It was performed before and after intervention. For biceps and triceps, subjects were sitting while the assessor stood behind the affected limb and extended the elbow from maximum flexion (biceps) or flexed the elbow from maximum extension (triceps) in V2 speed. For gastrocnemius, subjects lied supine on a mat table and the evaluator performed a fast (V2) dorsiflexion movement from a maximum plantar flexion. The MAS consists of six levels of spasticity, which range from 0, characterized as "normal tonus" or "no increase in muscle tone" to 4, "stiffness of affected part" or "limited range of motion". For statistical purposes, the MAS score (0, 1, 1+, 2, 3, 4) was considered as 0, 1, 1.5, 2, 3 and 4, respectively.

The secondary outcome, ROM, was assessed before and after intervention as well. For elbow flexion/extension the subjects were lying supine with the hand supinated and the arm parallel to the midline of the body and evaluator was standing next to him. The stationary arm of the goniometer was parallel to the humerus while the location of the axis was on the lateral epicondyle of the elbow. The patients were asked to actively flex or extend the elbow, then the evaluator passively continued the motion until the maximal range.

For the ankle, subjects lied supine on a mat and the assessor stood next to the affected limb. The axis of the goniometer was on the lateral calcaneus at bisection of fibula and 5th metatarsal. The stationary arm was parallel to fibula while the movement arm was in parallel to the 5th metatarsal. The patients were asked to actively plantar flex or dorsi flex the ankle, then the evaluator passively continued the motion until the maximal range.

II.4. Interventions:

All assessment was performed by the same physiotherapist, whereas the intervention applications were performed by another research team member. Participants were instructed to avoid any physical therapy session for at least 4 hours beforehand. All procedures were performed from 10 am to 4 pm, and subjects had a period of 15 min for acclimatization at the beginning of the assessment/intervention sessions.

II.4.1. Peripheral Joint Mobilization (PJM) Intervention Technique:

The patient is stationed in a supine position where the therapist stands on the ipsilateral side of the affected limb. When applying this technique to the shoulder, the therapist grabs the arm by wrapping one hand on the humeral area proximal to the axilla for the application of the force and the other on the outer aspect of the shoulder for the sense of direction and extra support of the mobilization. The arm is abducted 40-55 degrees at the shoulder and 30 degrees in flexion. (fig. 1)

Figure 1: PJM for glenohumeral joint

The therapist applies grade III Kaltenborn caudal, rostral, anterior, and posterior glides to the glenohumeral joint where each direction is applied 7 times to conclude a set without pausing between glides, over the course of 3 sets, and with a break interval of 30 seconds between each set.

When applying peripheral joint mobilization to the ankle, the patient is also in a supine position and the therapist stands on the ipsilateral side of the patient's ankle. The therapist grabs the calcaneus (which was placed in 90 degree) with one hand and positions the other hand on the anterior aspect of the distal leg just proximal to the talus. The therapist then applies anterior and posterior glides of the talocrural joint. The same application protocol is done; seven repetitions in each direction per set, over the course of three sets, and with a resting interval of 30 seconds between each set. (Fig. 2)

Figure 2: PJM for ankle joint

II.4.2. Cryotherapy Intervention Technique:

For cryotherapy intervention, a 200mL cup was filled with same level of water for each subject, frozen at the same temperature (4°C to 5°C) for 24 hours prior intervention. The ice cube then was held by the therapist using a towel.

For biceps brachii muscle, the patients were placed in a supine position, with elbow fully extended, and the therapist sitting on the ipsilateral side of the target area of the affected limb. (Fig. 3) A lateral position was adopted by the patient when applying the ice massage technique on the triceps region of the affected limb with the integration of a slight elevation of the arm, using a pillow, in order to reveal the surface area of the triceps muscle. (Fig. 4) For plantar flexors muscles, the optimal position was prone, but due to age factor, the lateral position was used for the application of the ice massage, with slight elevation of the leg so that the ice massage covers the whole region of the muscle. The patients wore shorts in order to avoid interferential compression on their legs during exercise. (fig. 5)

Figure 3: Ice massage technique applied for Biceps Bracii muscle

Figure 4: Ice massage technique applied for Triceps Bracii muscle

Figure 5: Ice massage technique in circular motion for gastrocnemius muscle

III. RESULTS AND STATISTICAL ANALYSIS

III.1. Data selection and distribution

III.1.1. Filtration of data:

Out of 21 subjects, 3 were excluded from the study. All data were calculated using SPSS (version 23)

III.1.2. Distribution of data:

III.1.2.1. Distribution of data among upper limb group:

16 subjects were distributed in the upper limb group, with 12 males (75%), and 4 (25%) females. The mean value of age was 61.8 +/- 9.5 SD (age ranged between 48 and 84 years). According to the dominant hand, 87% of the participants were right-handed, and 13% were left-handed, with 69% affected on the non-dominant side, and 31% had stroke on their dominant side. At baseline, biceps muscle evaluation indicated that 3 patients had no spasticity, 5 had a score on 1, 2 had score of 1+, 4 had score of 2, and 2 patients had a score of 3. Triceps muscle evaluation revealed that 6 patients had no spasticity, 1 with score 1, 3 with score 1+, 5 with score 2 and 1 with score 3. None of the patients had a score of 4 for both biceps and triceps muscles.

III.1.2.2. Distribution of data among lower limb group

14 participants were distributed in the lower limb group. Among these, there was 12 males (86%), and 2 (14%) females. The mean value of age among ankle group was 65.2, with +/- 11.04SD (age ranged between 48 and 91 years). According to dominant limb, 14% of the participant were left handed, and 86% were right handed, and 71% had the non-dominant side affected with stroke, while 29% had the dominant side affected. According to date of stroke, the majority of the patients (57%) had stroke since less than 10 years, with only 2 (14%) had an acute stroke (less than 6 months), and 4 patients (29%) had stroke since more than 10 years. At baseline, the majority of subject in ankle group had spasticity grade 4 in the plantar-flexors muscles (10 out of 14), and only 4 had grade 3.

IV. STATISTICAL TESTS

IV.1. Statistical Tests among upper limb group

A paired T-test was used to analyze the effect of PJM on biceps and triceps spasticity, before PJM and immediately after PJM. (Tables 2 and 3) The results show that there was a significant difference between Modified Ashworth Scale score before applying PJM compared to the immediate MAS score after applying PJM on spasticity in both biceps brachii and Triceps bracii muscles (p-value is < 0.05).

On the other hand, paired T test was also used to analyze the effect of Ice on biceps and triceps spasticity, before and immediately after Ice (Tables 4 and 5). The results show that there was a significant difference between Modified Ashworth Scale score before applying ice massage technique on second visit compared to the immediate MAS score after applying ice massage technique on spasticity in both biceps brachii muscle and triceps muscle (p-value <0.05)

Table 1. Paired T test between Ashworth for biceps muscle before PJM and after PJM

Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Ashworth for biceps before PJM - Ashworth for biceps after PJM	.375	.465	.116	.127	.623	3.223	15	.006

Table 2. Paired T test between Ashworth for triceps before PJM and after PJM

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Ashworth for triceps before PJM - Ashworth for Triceps after PJM	.34375	.43661	.10915	.11110	.57640	3.149	15	.007

Table 3. Paired T test between Ashworth of biceps before Ice and after Ice

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Ashworth for Biceps before Ice - Ashworth for Biceps after Ice	.45455	.65017	.19604	.01775	.89134	2.319	10	.043

Table 4. Paired T test between Ashworth of Triceps before Ice and after Ice

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Ashworth of Triceps before ICE - Ashworth of Triceps after ICE	.71429	.39340	.14869	.35045	1.07812	4.804	6	.003

IV.2.Statistical Tests among Ankle group

A paired T-test was used to analyze the effect of PJM on Ankle spasticity, before PJM and immediately after PJM. (Table 5) The results show that there was no significant difference between MAS score before applying PJM compared to immediate MAS score after applying PJM on spasticity in the gastrocnemius muscle (p-value is 0.082 > 0.05).

Table 5. Paired T test between Ashworth of Plantar-flexors before PJM and after PJM
Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Pair 1 Ashworth for gastro before PJM - Ashworth for gastro after PJM	.21429	.42582	.11380	-.03157	.46014	1.883	13	.082

To analyze the effect of ice on spasticity on plantar-flexor muscles, paired T test was also applied for ashworth, before and immediately after Ice. The results show that was a significant difference between Modified Ashworth Scale score before applying Ice compared to the MAS score after application of Ice on spasticity in the plantar-flexors muscle (p-value < 0.05).

Table 6. Paired T test between Ashworth of plantar flexors before Ice and after Ice
Paired Samples Test

	Paired Differences					t	Df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Pair 1 Ashworth for gastro Before Ice - Ashworth for gastro After Ice	1.07692	1.65638	.45940	.07598	2.07786	2.344	12	.037

For Range of Motion, the Paired T test showed that there is a significant difference between both passive and active dorsiflexion and plantarflexion range of motion before and immediately after applying PJM on the ankle. (p-value < 0.05). On the other hand, there was no significant difference between both active and passive dorsiflexion and plantarflexion range of motion before and immediately after applying ice massage technique on the gastrocnemius muscle. (p-value > 0.05).

The direct effect of cryotherapy and PJM is established for the first time, in terms of ice cube massage for 5 minutes and using Kaltenborn's for joint mobilization, on spasticity levels in stroke patients. The new applied techniques will open new research horizons in the field of spasticity management, taking into consideration this was a pioneering study in neuro-rehabilitation domain.

V. DISCUSSION

Spasticity is considered a complex problem that heavily affects the activities of daily life of the patients and give rise to significant difficulties in the process of rehabilitation (Balci, 2018, Ghai et al, 2013).

In this study, we intended to investigate the effect of cryotherapy (ice massage modality) and peripheral joint mobilization (PJM) immediately on spasticity level, measured with Modified Ashworth Scale (MAS), and the range of motion, measured with a goniometer, for ankle and elbow in patients post-stroke.

Each patient was subjected to the two modalities in two different sessions, with 2 days interval between each. PJM was applied in the first session, using Kaltenborn's technique, followed by cryotherapy on the second session, using ice massage technique for 5 minutes. The assessment was done prior and after each intervention, and analyzed using SPSS.

V.1. Peripheral Joint Mobilization:

V.1.1.Effect of PJM on spasticity:

Peripheral joint mobilization is a non-thrust, low-amplitude and low-velocity technique used in manual therapy approach to typically modulate pain and treat limited range of motion by addressing a joint's altered mechanics. Our intervention consisted of 3 sets, with 7 repetitions each, of grade III low-amplitude and low-velocity peripheral joint mobilizations in four directions: caudal, rostral, anterior, and posterior glides, according to Kaltenborn's technique. The patient is subjected to a break interval of 30 seconds between each set. After reviewing previous studies concerning the effects of peripheral joint mobilization in stroke patients, we have not encountered one that had investigated the immediate effect of PJM alone on spasticity in stroke patients. In addition to that, we used a specific technique in mobilization where we applied it using unique parameters and method, which were not done before, in terms of single-modality usage, sets, repetitions, glide directions, intervals, etc. We focused on exploring the effects of PJM by itself on spasticity without the probable interference of other modalities that may affect the results. Thus, we abode by our protocol that did not include any other physiotherapy interventions or sessions that could have had the potential to hinder the purity of our results. In order to make our study even more distinctive, we applied our PJM technique on the shoulder girdle and assessed spasticity level on the Biceps Brachii and Triceps muscles. The rationale behind assessing those muscles is that, according to (B. J. Lehecka et al., 2018, p. 7), joint mobilization generates both local and distal neurophysiological effects hence we hypothesized at the beginning of our study that the distal effects may cover these mentioned muscles.

Our results indicate significant positive changes in spasticity in Biceps Brachii and Triceps muscles, but no significant positive changes in gastrocnemius muscle, immediately after the application of the peripheral joint mobilizations

V.1.1.1.In Biceps Brachii and Triceps muscles:

The results of the Biceps Brachii and Triceps muscles directly after the application of PJM are similar to those of a study conducted by Park and Youn (2017) where they investigated the immediate effect of wrist joint mobilization on spasticity. Unlike our technique approach, they applied posterior-anterior mobilizations for about 10 minutes to the scaphoid and lunate in a manner of 30-60 oscillations per minute in grade II-III for 3 sets, where after each set the patient receives a 1-minute break. In addition to the dissimilarity, they used kinesiology taping post-mobilization. Nevertheless, they found positive changes in spasticity in the mobilization and taping group (experimental) compared to the taping group (control) where there were no changes.

The findings in the positive spasticity changes in the upper limb muscles in our study are also coherent with Smedes et al. (2014) where they applied wrist joint mobilizations and monitored spasticity changes as a secondary outcome, though they used a 6-week intervention plan.

On the other hand, spinal manipulations' positive short-term effect on spasticity had been shown in a randomized clinical trial by Oleh et al. (2018) where they applied spinal manipulations to spastic cerebral palsy patients (aged 7 to 18 years) and evaluated after 5 minutes.

The previous studies hint that experiments that aim at investigating the effect of peripheral joint mobilization (low-amplitude and low-velocity) on spasticity in patients with stroke as a primary outcome are scarce, if not absent. In addition to the fact that those studies were carried out on the course of long durations and none, with the exception of Park and Youn's study, conducted as an immediate-effect trial.

V.1.1.2.In Gastrocnemius muscle:

Previous studies regarding the effects of joint mobilizations on lower limbs investigated balance, gait, proprioception, and range of motion but did not measure spasticity changes especially immediately after the intervention. Our inclusion of measuring the gastrocnemius' spasticity is considered a unique addition to the experiment. Furthermore, our peripheral joint mobilization technique applied on the ankle differs from other studies where we performed anterior-posterior glides of the ankle joint as well as the difference in the timing of the evaluation and technique application.

Our results suggest that peripheral joint mobilization does not show an immediate effect on spasticity in the gastrocnemius muscle according to the re-assessment done directly after the intervention using modified ashworth scale. Previously performed studies support that joint mobilization showed decrease in spasticity on a long-term program application with an extensive protocol – a certain number of sessions per week over several weeks – but what differs in our study is that we applied the technique only once and measured immediately.

In an attempt to label reasons behind the difference between the results of the same technique shown on the upper limb muscles in comparison to those of the gastrocnemius muscle, we may put several probable causes and reasons on display. We reviewed the patient's initial MAS scores and marked that patients had grade 4 spasticity in the gastrocnemius muscle, unlike spasticity in Biceps Brachii and Triceps muscles where we did not find such a grade in any of the patients in those muscles. This is a rather important remark since patients with grade 4 spasticity were excluded from previous studies while we included them. On the other hand, subjective feedback taken from the examiner during the immediate assessment of MAS on the first visit remarked that, even though grade 4 spasticity remained, there was a felt decrease in the associated clonus. Other reasons could include the cortical homunculus representation that shows the complexity of the mapping of the arm in the cortex, according to (Meier et al., 2008), in addition to the proximity and functional capacity of the arm in comparison the foot and ankle. We considered acknowledging internal factors such as emotional distress, anxiousness, mood changes and sways, nervousness, fear, etc. and other factors that include daily conflicts that may change from day to day. The chance of those mentioned factors being the obstacles behind the no change in the gastrocnemius' spasticity level immediately is not high; if those factors affected the results of the ankle plantarflexor then they should have affected the immediate results of the Biceps Brachii and Triceps muscles as well.

V.1.2.Effect of PJM on ankle's ROM:

Regarding the ankle's range of motion post-intervention, we found positive significant results in both the ankle dorsiflexion and plantarflexion, whether active or passive. Assessment was done directly before and after the application of PJM on the first day using a goniometer by a professionally trained physiotherapist. Our results reveal consistency with a study conducted by (Kyun-Hee Cho et al., 2020) on stroke patients where they performed sustained posterior talar glide for 1 minute with an overall timing of 15 minutes, over the course of 6 weeks and 3 days/week, where they found significant improvement in the ankle's dorsiflexion range of motion. Other previous studies have used other techniques of joint mobilization – such as self-mobilization with movement, therapist-induced mobilization with movement, and rhythmic oscillations – that showed positive effects on the ankle's range of motion but each's experiment ranged from 4 to 6 weeks. Those studies were a randomized clinical trial by (Cho et al., 2020), two randomized clinical trials by (Cho et al., 2019), and two randomized clinical trials by (An et al., 2016) and (An et al., 2017).

It is shown that previous studies, which have indicated positive results on the ankle's range of motion after the application of different peripheral joint mobilization techniques, had covered their intervention programs over the course of weeks; unlike our experiment where our results were found in a matter of days.

V.2. Cryotherapy

In the present study, cryotherapy was applied to elbow flexor and extensor muscles and ankle plantar-flexor muscles. The technique consisted of moving the ice cube slowly from origin to insertion, maintaining a continuous and direct contact in circular motion for 5 minutes over each area of biceps, triceps and plantar-flexor muscles, aiming to gain a significant reduction in spasticity and an increase in ROM. Our findings showed that cryotherapy did decrease the elbow flexor/extensor and plantar-flexor tonus according to the Modified Ashworth Scale ($p<0.05$). However, it did not interfere with the ROM of both dorsal and plantar flexion.

V.2.1.Effect of Cryotherapy on spasticity:

According to our results, ice can temporarily decrease spasticity level in patients with stroke. This is supported by previous studies that have also shown a decrease in spasticity level of muscles following cryotherapy application in subjects with neurological injury.

Regarding stroke, two studies, done by Alcantara et al (2019) and Garcia et al (2018), showed similar results to ours in respect to reducing spasticity. Both applied ice pack enrolled over plantar flexor muscle for 20 minutes which reduced muscle tone. (Alcantara et al, 2019, Garcia et al, 2019) Moreover, Elanchezhian et al (2019) in their study showed corresponding results on diplegic children with CP, using also ice pack for 20 min over different spastic muscles in lower limbs.

The cooling time required to decrease spasticity, as we mentioned before, is controversial. Unanimously in most of the studies, cryotherapy was applied for 20 mins using ice packs, immersion or cold air therapy. Lee et al (2002) showed that muscle temperature should be reduced in order to achieve effective decrease in excitatory impulses, thus decreasing spasticity. Hence, he recommended applying cryotherapy for at least 25-30 minutes, which is the ideal time to reduce muscle temperature. This could be the reason behind why most of studies used this timing to obtain results.

The unique aspects of our study were the technique used and the timing. Ice massage was found to have a positive effect on spasticity within 5 minutes of application only. Given to what we know, only one study done by Dr. Darade (2015) used a similar technique, by applying ice cube massage in circular motion on plantar-flexor muscle. However, he applied this technique for 30 continuous minutes, while we used it for only for 5 minutes. Both timing showed decrease in spasticity level, measured by MAS.

Although both ice packs and ice massage transmit heat through conduction, Zemke et al (1998) proved in his study that ice massage is capable of changing muscle temperature in a higher velocity than ice packs can do, due to the greater promotion of cooling effects via great heat loss from conduction. In addition, the pressure applied to the skin through massage may enhance the penetration of cold throughout the muscle, which is supported by Warren et al. (1971) who concluded that deep prolonged and penetrating cold could be used in therapy to induce relaxation, by producing cold block of the receptors or the afferent fibers themselves.

A more plausible explanation to the positive effect of ice massage within shorter period application is the mechanism demonstrated by Michlovitz et al. (1988) who stated that inhibition occurring due to the use of cryotherapy may be due to the local cooling effect on every component of the segmental sensorimotor complex, including large afferent fibers of muscle spindles (both alpha and gamma motoneurons), all skin receptors, extrafusal muscle fibers and the myoneural junction. This might be stimulated and achieved, as shown by our results, within 5 minutes of applying ice massage, in circular motion, possibly due to the continuous contact on the skin and the larger surface area covered.

Our findings disagree with Nilsaga et al (2016) study, who found no effect of wearing a cooling garment for 45 minutes, in a single session, on spasticity for MS patients. It may be argued that the cooling garment was not in direct contact with subject's skin, while the present technique intended to maintain a continuous and direct touch of the ice cube on the skin, which may explain the discrepancy in the outcomes. (Nilsaga et al, 2006)

Even though our study supports the findings of Price et al (1993) regarding muscle tone reduction by cryotherapy, yet a dichotomous effect in spasticity was reported by him, where some patients had an increase in MAS score after ice pack application. He linked this paradoxical finding to the assumption that the deep muscle cooling is not uniform using the clinical method of ice pack application. Meanwhile, according to our results, ice massage has decreased spasticity in most of the patients, which emphasizes the idea that this technique is more precise since it is applied in a consistent manner all over the muscle area.

V.2.2.Effect of Cryotherapy on ROM:

As a secondary outcome, ROM was assessed using goniometer prior and after cryotherapy application.

The results of our study revealed no significant improvement in ankle ROM. This disagrees with results of Gehan M et al, 2011 who showed in their study that cryotherapy, when used in combination with conventional physical and occupational therapy decreases spasticity and increases elbow and wrist ROM in CP patients. Gehan associated this to the fact that reduction of spasticity allows the antagonistic muscles to work in an opposite direction without restriction from spastic agonist, in addition to the analgetic effect of ice which encourage in achieving maximum ROM as much as possible during exercises. These disparities could be related to differences in the session frequency and conventional interventions. Our experiment consisted of a single icing session, of 5 minutes' duration, with no other additional physical therapy intervention.

It is possible that by increasing the frequency or timing of ice application some changes may have occurred, as was shown by Dr Darade in his study, who found an increase in ankle ROM after applying ice cube massage for 30 minutes. Therefore, 5 minutes could have not been enough to trigger any change in ROM.

It is crucial to understand whether, and to which extent, cryotherapy application leads to positive, negative or no effects on ROM. Although in our study, on an overall basis, ice cube massage did not affect both passive and active ankle ROM, on an individual basis, 2 of the 14 tested subjects showed a decrease in active dorsiflexion ROM. A potential interpretation for this is that cooling reduces the nerve conduction velocity (NCV) and prolongs the latency and duration of the compound muscle and sensory action potentials, which inhibits the motor response, as stated by Herrera et al, 2010. This corroborates the possible adverse effect of cryotherapy on active muscle contraction, which encourages the idea of applying cryotherapy in a shorter interval of time.

In accordance with the current study findings, it was reported from the patients a direct relief after ice massage application in both tone and movement. Some stated a "more flexible feeling" obtained in the targeted limb after the intervention, others revealed an "ease while walking" and a "decrease in pain".

The subjective contentment obtained by patients combined with the significant objective results provide important findings regarding the parameters of cryotherapy application. Reducing the time interval is more practical and more easily accepted by the patient, since most of the patients were disturbed while applying ice. In addition, this allows the therapist to introduce other rehabilitation modalities during the same session, with enhancement in the patient's performance.

VI. Limitations:

The results of this study must be considered for its limitations. We should shed light on the fact that we sought different rehabilitation centers and hospitals to acquire as much patients as we could. We did not receive entry permission to Mohammad Khaled Foundation, in which we were expecting to receive around 15 patients from there alone, due to the health concerns regarding the current COVID-19 pandemic even though our team's complied with the health safety measurements and conducted PCR tests a day before the start of the experiment. We turned the disadvantage into an advantage by applying both modalities on the same patients, with duration gap between both, so that we mark their effects on the same individuals with the same physical and physiological interactions and reactions. Our team consists of professionally trained physiotherapists and including an outsider, to make the study blinded, was somewhat a risk to the experiment since we trust our team's precise technique application and assessment skills. Additionally, there were no professionally experienced physiotherapists available to conduct a blinded experimentation so we chose them from our own trusted and skillful research team.

VII. CONCLUSION AND RECOMMENDATIONS

Stroke was classified as the third leading cause of acquired adult disability including spasticity, which could have a significant impact on quality of life. As means of spasticity interventions, our results suggest that Kaltenborn's grade III PJM in caudal, rostral, anterior, and posterior directions applied to the glenohumeral joint, and anterior-posterior glides on the ankle joint, in 7 repetitions over 3 sets with 30 seconds-interval break between each set and cryotherapy, ice massage modality applied in circular motion on the biceps brachii, triceps brachii, and gastrocnemius muscles over the duration of five continuous minutes, were both are effective in decreasing tonus level according to the Modified Ashworth Score, yet PJM is shown to be significant in increasing both active and passive range of motion.

In future studies, expanding the pool of stroke patients participating in the study is recommended. Furthermore, upcoming investigations should conduct a single blinded randomized clinical trial where groups are divided into PJM group, cryotherapy group, combined therapy group, and an optional sham group to compare the effects of both modalities with each other on spasticity.

We also recommend assessing the effect of a single-session of both PJM and cryotherapy after more than two days to monitor the long-term effects of those modalities. It is also possible to reapply those modalities as programs on their own on a longer term without other associated physiotherapy interventions to monitor their sole effects on spasticity.

REFERENCESF

I. Alcantara, C. C., Blanco, J., De Oliveira, L. M., Ribeiro, P., Herrera, E., Nakagawa, T. H., Reisman, D. S., Michaelsen, S. M., Garcia, L. C., & Russo, T. L. (2019). Cryotherapy reduces muscle hypertonia, but does not affect lower limb strength or gait kinematics post-stroke: a randomized controlled crossover study. *Topics in stroke rehabilitation*, *26*(4), 267–280.

II. An, C. M., & Jo, S. O. (2017). Effects of Talocrural Mobilization with Movement on Ankle Strength, Mobility, and Weight-Bearing Ability in Hemiplegic Patients with Chronic Stroke: A Randomized Controlled Trial. Journal of stroke and cerebrovascular diseases: the official journal of National Stroke Association, 26(1), 169–176.

III. An, C. M., & Jo, S. O. (2017). Effects of Talocrural Mobilization with Movement on Ankle Strength, Mobility, and Weight-Bearing Ability in Hemiplegic Patients with Chronic Stroke: A Randomized Controlled Trial. *Journal of stroke and cerebrovascular diseases: the official journal of National Stroke Association*, 26(1), 169–176.

IV. An, C. M., & Won, J. I. (2016). Effects of ankle joint mobilization with movement and weight-bearing exercise on knee strength, ankle range of motion, and gait velocity in patients with stroke: a pilot study. Journal of physical therapy science, 28(2), 689–694.

V. An, C. M., & Won, J. I. (2016). Effects of ankle joint mobilization with movement and weight-bearing exercise on knee strength, ankle range of motion, and gait velocity in patients with stroke: a pilot study. *Journal of physical therapy science*, 28(2), 689–694.

VI. Bagg, S., Pombo, A. P., & Hopman, W. (2002). Effect of age on functional outcomes after stroke rehabilitation. *Stroke*, *33*(1), 179–185.

VII. Balci B. P. (2018). Spasticity Measurement. *Noro psikiyatri arsivi*, *55*(Suppl 1), S49–S53.

VIII. Bassett, S. W., & Lake, B. M. (1958). Use of Cold Applications in the Management of Spasticity. Physical Therapy, 38(5), 333–334.

IX. Bell, K. R., & Lehmann, J. F. (1987). Effect of cooling on H- and T-reflexes in normal subjects. *Archives of physical medicine and rehabilitation*, *68*(8), 490–493.

X. Bethoux, F. (2015). Spasticity Management After Stroke. Physical Medicine and Rehabilitation Clinics of North America, 26(4), 625–639.

XI. Boyd, R. N., & Ada, L. (n.d.). Physiotherapy management of spasticity. Upper Motor Neurone Syndrome and Spasticity, 79–98.

XII. Cheung, J., Rancourt, A., Di Poce, S., Levine, A., Hoang, J., Ismail, F., Boulias, C., & Phadke, C. P. (2015). Patient-identified factors that influence spasticity in people with stroke and multiple sclerosis receiving botulinum toxin injection treatments. *Physiotherapy Canada. Physiotherapie Canada*, *67*(2), 157–166.

XIII. Cho, K. H., & Park, S. J. (2020). Effects of joint mobilization and stretching on the range of motion for ankle joint and spatiotemporal gait variables in stroke patients. Journal of stroke and cerebrovascular diseases: the official journal of National Stroke Association, 29(8), 104933.

XIV. Cho, K. H., & Park, S. J. (2020). Effects of joint mobilization and stretching on the range of motion for ankle joint and spatiotemporal gait variables in stroke patients. *Journal of stroke and cerebrovascular diseases: the official journal of National Stroke Association*, 29(8), 104933.

XV. Darade, S. (2015). Can icing is help to reduce Spasticity, improving ankle range of motion and gait velocity in post stroke subjects.

XVI. Denton, A., Bunn, L., Hough, A., Bugmann, G., & Marsden, J. (2016). Superficial warming and cooling of the leg affects walking speed and neuromuscular impairments in people with spastic paraparesis. *Annals of physical and rehabilitation medicine*, *59*(5-6), 326–332.

XVII. Elanchezhian, Ch, Swarnakumari, P. Efficacy of Cold Therapy and Passive Stretching to Improve Gait in Spastic Diplegic Cerebral Palsy Children. Int J Pediatr 2019; 7(9): 10109-118.

XVIII. El-Hajj, M., Salameh, P., Rachidi, S., & Hosseini, H. (2016). The epidemiology of stroke in the Middle East. European Stroke Journal, 1(3), 180–198.

XIX. El-Maksoud, G., Sharaf, M.A., & Rezk-Allah, S.S. (2011). Efficacy of cold therapy on spasticity and hand function in children with cerebral palsy. *Journal of Advanced Research, 2*, 319-325.

XX. El-Maksoud, G., Sharaf, M.A., & Rezk-Allah, S.S. (2011). Efficacy of cold therapy on spasticity and hand function in children with cerebral palsy. *Journal of Advanced Research, 2*, 319-325.

XXI. Felice, T. D., & Santana, L. R. (2009). Recursos Fisioterapêuticos (Crioterapia e Termoterapia) na espasticidade: revisão de literatura. *Revista Neurociências*, *17*(1), 57–62.

XXII. Fink, J. N., Frampton, C. M., Lyden, P., Lees, K. R., & Virtual International Stroke Trials Archive Investigators (2008). Does hemispheric lateralization influence functional and cardiovascular outcomes after stroke?: an analysis of placebo-treated patients from prospective acute stroke trials. *Stroke*, *39*(12), 3335–3340.

XXIII. Fink, J. N., Frampton, C. M., Lyden, P., Lees, K. R., & Virtual International Stroke Trials Archive Investigators (2008). Does hemispheric lateralization influence functional and cardiovascular outcomes after stroke?: an analysis of placebo-treated patients from prospective acute stroke trials. *Stroke*, *39*(12), 3335–3340.

XXIV. Garcia, L. C., Alcântara, C. C., Santos, G. L., Monção, J. V. A., & Russo, T. L. (2018). Cryotherapy reduces muscle spasticity but does not affect proprioception in ischemic stroke. American Journal of Physical Medicine & Rehabilitation.

XXV. Ghai, A., Garg, N., Hooda, S., & Gupta, T. (2013). Spasticity - Pathogenesis, prevention and treatment strategies. *Saudi journal of anaesthesia*, *7*(4), 453–460.

XXVI. *Global Health Estimates: Life expectancy and leading causes of death and disability*. (2019). World Health Organization. https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates

XXVII. Guimarães, S. S. F., Coelho, C. de F., & Carruba, L. B. (2014). Effects of cryotherapy on tonic adequacy upper limb hemiparesis after stroke. *Manual Therapy, Posturology & Rehabilitation Journal*, 1-9.

XXVIII. Hankey, G. J., Jamrozik, K., Broadhurst, R. J., Forbes, S., & Anderson, C. S. (2002). Long-Term Disability After First-Ever Stroke and Related Prognostic Factors in the Perth Community Stroke Study, 1989-1990. Stroke, 33(4), 1034–1040.

XXIX. Harris, J. E., & Eng, J. J. (2006). Individuals with the dominant hand affected following stroke demonstrate less impairment than those with the nondominant hand affected. *Neurorehabilitation and neural repair*, *20*(3), 380–389

XXX. Hegedus, E. J., Goode, A., Butler, R. J., & Slaven, E. (2011). The neurophysiological effects of a single session of spinal joint mobilization: does the effect last?. The Journal of manual & manipulative therapy, 19(3), 143–151.

XXXI. Herrera, E., Sandoval, M. C., Camargo, D. M., & Salvini, T. F. (2010). Motor and sensory nerve conduction are affected differently by ice pack, ice massage, and cold water immersion. *Physical therapy*, *90*(4), 581–591.

XXXII. Kachmar, O., Kushnir, A., Matiushenko, O., & Hasiuk, M. (2018). Influence of Spinal Manipulation on Muscle Spasticity and Manual Dexterity in Participants With Cerebral Palsy: Randomized Controlled Trial. Journal of chiropractic medicine, 17(3), 141–150.

XXXIII. Kachmar, O., Kushnir, A., Matiushenko, O., & Hasiuk, M. (2018). Influence of Spinal Manipulation on Muscle Spasticity and Manual Dexterity in Participants With Cerebral Palsy: Randomized Controlled Trial. *Journal of chiropractic medicine*, 17(3), 141–150

XXXIV. Kachmar, O., Voloshyn, T., & Hordiyevych, M. (2016). Changes in Muscle Spasticity in Patients with Cerebral Palsy After Spinal Manipulation: Case Series. Journal of chiropractic medicine, 15(4), 299–304.

XXXV. Kaltenborn FM, Kaltenborg FM, Kaltenborn TB, Vollowitz E, Evjenth O, Morgan D. Manual Mobilization of the Joints: The Kaltenborn Method of Joint Examination and Treatment: Traction-Manipulation of the Extremities and Spine. Oslo: Norli; 2008

XXXVI. Khandare, S., & Palekar, T. (2012). Comparison of post 24 hours effect of cooling and sustained passive stretching as treatment techniques for reduction of spasticity in hemiplegics using h-reflex -. *International journal of current research and review*, *4*, 144-148.

XXXVII. Kim, Y.-H., Jang, H.-J., & Kim, S.-Y. (2014). Effect of Hip Joint Mobilization on Hip Mobility, Balance and Gait With Stroke Patients. Physical Therapy Korea, 21(2), 8–17.

XXXVIII. Knutsson E. (1970). Topical cryotherapy in spasticity. *Scandinavian journal of rehabilitation medicine*, *2*(4), 159–163.

XXXIX. Krukowska, J., Dalewski, M., & Czernicki, J. (2014). Ocena skuteczności krioterapii miejscowej u osób ze spastycznością po udarze mózgu [Evaluation of effectiveness of local cryotherapy in patients with post-stroke spasticity]. *Wiadomosci lekarskie (Warsaw, Poland: 1960)*, *67*(2 Pt 1), 71–75.

XL. Kuo, C.-L., & Hu, G.-C. (2018). Post-stroke Spasticity: A Review of Epidemiology, Pathophysiology, and Treatments. International Journal of Gerontology.

XLI. Lee, S. U., Bang, M. S., & Han, T. R. (2002). Effect of cold air therapy in relieving spasticity: applied to spinalized rabbits. *Spinal cord*, *40*(4), 167–173.

XLII. Lundström, E., Smits, A., Terént, A., & Borg, J. (2010). Time-course and determinants of spasticity during the first six months following first-ever stroke. Journal of Rehabilitation Medicine, 42(4), 296–301.

XLIII. Macciocchi, S. N., Diamond, P. T., Alves, W. M., & Mertz, T. (1998). Ischemic stroke: relation of age, lesion location, and initial neurologic deficit to functional outcome. *Archives of physical medicine and rehabilitation*, *79*(10), 1255–1257.

XLIV. Manske, R. C., Lehecka, B. J., Reiman, M. P., & Loudon, J. K. (2018). *Orthopedic Joint Mobilization and Manipulation: An Evidence-Based Approach* (First ed.). Human Kinetics.

XLV. Martins, F. L., Carvalho, L. C., Silva, C. C., Brasileiro, J. S., Souza, T. O., & Lindquist, A. R. (2012). Immediate effects of TENS and cryotherapy in the reflex excitability and voluntary activity in hemiparetic subjects: a randomized crossover trial. *Revista brasileira de fisioterapia (Sao Carlos (Sao Paulo, Brazil)), 16*(4), 337–344.

XLVI. Meier, J. D., Aflalo, T. N., Kastner, S., & Graziano, M. S. (2008). Complex organization of human primary motor cortex: a high-resolution fMRI study. *Journal of neurophysiology*, 100(4), 1800–1812.

XLVII. Michlovitz, S. L., Smith, W., & Watkins, M. (1988). Ice and high voltage pulsed stimulation in treatment of acute lateral ankle sprains*. *The Journal of orthopaedic and sports physical therapy*, *9*(9), 301–304.

XLVIII. Mulligan, BR: Mobilizations with movement (MWM'S). J Manual Manipulative Ther 1(4):154, 1993.

XLIX. Nilsagård, Y., Denison, E., & Gunnarsson, L. G. (2006). Evaluation of a single session with cooling garment for persons with multiple sclerosis--a randomized trial. *Disability and rehabilitation. Assistive technology*, *1*(4), 225–233.

L. Park SJ, Youn PS. (2017). The immediate effect of wrist joint mobilization with taping on range of motion, grip strength, spasticity in stroke patients. *J Kor Phys Ther*; 29(4):187–93.

LI. Park SJ, Youn PS. The immediate effect of wrist joint mobilization with taping on range of motion, grip strength, spasticity in stroke patients. J Kor Phys Ther. 2017;29(4):187–93.

LII. Park, D., Cynn, H. S., Yi, C., Choi, W. J., Shim, J. H., & Oh, D. W. (2020). Four-week training involving self-ankle mobilization with movement versus calf muscle stretching in patients with chronic stroke: a randomized controlled study. *Topics in stroke rehabilitation*, *27*(4), 296–304.

LIII. Park, D., Lee, J. H., Kang, T. W., & Cynn, H. S. (2019). Four-week training involving ankle mobilization with movement versus static muscle stretching in patients with chronic stroke: a randomized controlled trial. *Topics in stroke rehabilitation*, 26(2), 81–86.

LIV. Price, R., Lehmann, J. F., Boswell-Bessette, S., Burleigh, A., & deLateur, B. J. (1993). Influence of cryotherapy on spasticity at the human ankle. Archives of physical medicine and rehabilitation, 74(3), 300–304.

LV. Pt Ms, K. C., Pt Ms, C. L. A., & Pt, B. J. (2017). Therapeutic Exercise: Foundations and Techniques (Therapeudic Exercise: Foundations and Techniques) (7th ed.). F.A. Davis Company.

LVI. Pundik, S., McCabe, J., Skelly, M., Tatsuoka, C., & Daly, J. J. (2019). Association of spasticity and motor dysfunction in chronic stroke. *Annals of physical and rehabilitation medicine*, *62*(6), 397–402.

LVII. References without background

LVIII. Saunders, D. G., Walker, J. R., & Levine, D. (2005). Joint mobilization. The Veterinary clinics of North America. Small animal practice, 35(6), 1287–viii.

LIX. Smedes, F., van der Salm, A., Koel, G., & Oosterveld, F. (2014). Manual mobilization of the wrist: a pilot study in rehabilitation of patients with a chronic hemiplegic hand post-stroke. *Journal of hand therapy: official journal of the American Society of Hand Therapists*, 27(3), 209–216.

LX. Svomp, H. E. M. B. O., & Srp, B. K. B. M. (2005). Maitland's Peripheral Manipulation: Management of Neuromusculoskeletal Disorders - Volume 2 (4th ed.). Butterworth-Heinemann

LXI. Urban, P. P., Wolf, T., Uebele, M., Marx, J. J., Vogt, T., Stoeter, P., … Wissel, J. (2010). Occurence and Clinical Predictors of Spasticity After Ischemic Stroke. Stroke, 41(9), 2016–2020.

LXII. Wall PD, Melzack R. On nature of cutaneous sensory mechanisms. Brain. 1962;85: 331-356

LXIII. Warren, C. G., Lehmann, J. F., & Koblanski, J. N. (1971). Elongation of rat tail tendon: effect of load and temperature. *Archives of physical medicine and rehabilitation*, *52*(10).

LXIV. Youn, P. S., Cho, K. H., & Park, S. J. (2020). Changes in Ankle Range of Motion, Gait Function and Standing Balance in Children with Bilateral Spastic Cerebral Palsy after Ankle Mobilization by Manual Therapy. Children (Basel, Switzerland), 7(9), 142.

LXV. Zemke, J. E., Andersen, J. C., Guion, W. K., McMillan, J., & Joyner, A. B. (1998). Intramuscular temperature responses in the human leg to two forms of cryotherapy: ice massage and ice bag. *The Journal of orthopaedic and sports physical therapy*, *27*(4), 301–307.