COLD-WATER-IMMERSION AND THE INFLUENCE OF DYNAMIC BALANCE TASK AND POSTURAL SWAY

by

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ABSTRACT

Ankle sprains in an athletic setting are considered one of the most common injuries sustained. Cryokinetics is commonly used in the treatment of these injuries. Recent literature suggests dynamic balance rehabilitation is influential for faster return to functional activity. Limited research has been published on the influence Cold-Water-Immersion (CWI) has on dynamic balance performance at the ankle. We evaluate CWI influence on a modified y-balance test and postural sway. We anticipated no significant differences between a treatment and control. Alpha was set at ≤ 0.05. A crossover design was utilized with a randomized treatment and control day along with randomized reach direction. Data collection was performed in a research laboratory setting with thirty subjects (female=15 male=15, age= 24±1.5 years, ht =172.75 cm±8.0, mass=70.8±12.8 kg). Study took place over two separate data collection days consisting of treatment and control. Treatment included subjects placing the nondominant lower leg into a container of cold water (maintained between 0 - 5 °C) for a minimum of 10 minutes and maximum of 15 minutes along with self reported numbness. Post treatment, subjects were asked to perform a modified y-balance test on a force plate. If numbness was lost during testing, the subject placed the lower leg back into the container for a minimum of 5 minutes and self-reported numbness. Normalized reach direction in the anterior (ANT), posteromedial (PM), and posterolateral (PL) were recorded with an intratester reliability of (0.67-0.96). Center of Pressure (COP) excursions of means velocity squared via forceplate was calculated with anterior/posterior (R=0.86) and medial/lateral (R=0.81) values. Normalized reach and COP measures were compared using RMANOVA. There was no significant within-subject interaction on all variables [Wilks' Λ=0.70, F (df) = 0.999, p = 0.471]. ANT reach presented closest to significance and largest effect size [F=2.51, p = 0.123, effect size = 0.33]. However, subjects self-reported an increased difficulty during testing. Measures indicate no significant difference in performance of the dynamic balance task. This may reinforce earlier dynamic balance rehabilitation of acute ankle sprains. With a faster introduction to rehabilitative exercises, athletes may minimize the long-lasting effects experienced from acute ankle sprains. Further research should evaluate the effect dynamic balance has on an injured population.

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INTRODUCTION

Cryokinetics is one of the most common treatments used for ankle sprains in an acute clinical setting. With its increased surface area of cooling, the ankle is subjected to a global cryotherapy treatment, providing a more efficient application of cryotherapy. Cryotherapy can quickly cool the area, minimizing pain and secondary injury.[1,2] With the therapeutic numbing effect of cryotherapy, patients can perform more advanced kinetic actions at the ankle, including range of motion exercises, resistance bands, and even weight bearing activities.[2]

Ankle sprains are one of the most common lower extremity injuries in the sports medicine setting, with some literature reporting estimates that they account for 45% of all athletic injuries.[3] Dynamic balance has been reported to be an influential part of prevention for individuals suffering from reoccurring ankle sprains.[3-7] As the understanding of return to play for ankle sprains becomes more clear, balance training (along with progressive strengthening) are beginning to become equally important in a normal rehabilitative plan.[3-5,7]

To date, there has been limited research on cryokinetics and its influence on the protocol for acute care management.[3] Previous investigators have evaluated the effect of cryotherapy on proprioceptive reactions and muscular activation at the lower extremity.[8-12] The research performed by Thieme et al. evaluated cryotherapy's influence on the knee in a proprioceptive sense and illustrated how there was no adverse effect on proprioception.[13] In comparison, Douglas et al.[11] reported that Cold-Water-Immersion (CWI) had a negative effect on the ankle. However, this study involved patients standing on a balance board and did not ask subjects to perform a dynamic balance task similar to that in a rehabilitative setting. The study performed by Fullam et al. was most similar to a true cryokinetic dynamic balance task.[8] This research found a negative relationship between decrease in reach-distance score of a dynamic balance task and Center of Pressure (COP) velocity measurements. However, cryotherapy application was administered via a "sleeve" and did not utilize the conductive properties of water, thus lacking true CWI effect on a dynamic balance task. The modality was also applied for 15-mintues during treatment instead of the recommended 10-minutes. The authors also failed to mention if subjects reported themselves as "numb" to the effects of the modality, which may have allowed for a "rewarming period" causing an increase in sensation.[8]

Recently, there has been evidence to show that cryotherapy does not cause an increase in tissue stiffness or a decrease of range of motion.[14] This research also noted the lack of influence an ice bag has on electromyography measurements and maximum voluntary contraction. As presented by Akehi K, there is little evidence to suggest musculotendinous stiffness occur as a result of cryotherapy.[14]

To date, there has been no study on dynamic balance relationship with true cold-water immersion and COP. Therefore, the purpose of this study is to evaluate how CWI can effect dynamic stability on a modified y-balance testing protocol and COP measurements. We hypothesize that there will be no significant differences when comparing CWI and a control group with respect to normalized y-balance reach scores and COP measurements.

MATERIALS AND METHODS

Subjects

Thirty subjects (female = 15 male =15, age=24±1.5 years, ht=172.75 cm ± 8.0, mass = 70.8±12.8 kg) completed this investigation. Subjects were screened to have the ability to perform at least one single leg squat to parallel with the floor without loss of balance in their nondominant leg (i.e., opposite leg used to kick a ball). Prior to participation, each subject completed a health history questionnaire to ensure they had no history of cold hypersensitivity, circulatory complications such as Raynaud's phenomena, lower extremity injury, previous ankle, knee or hip surgery within the past two years, or taking an over-the-counter or prescription pain medication. Subjects were also asked if they had exercised moderate to strenuously over the past 12 hours. This was performed to minimize the risk of fatigue in the subject's tested extremity. To ensure subjects did not have cold hypersensitivity, subjects received a hypersensitivity test. This involved having an ice massage on the subject's left anterior forearm for 1 minute. If an abnormal response occurred (i.e., cold induced urticaria) during or following the application, subjects were excluded from the study. The University of Utah's Institutional Review Board approved all procedures and subjects provided written consent before testing.

Study Design

We used a crossover design to guide data collection. The independent variables were treatment (ice or no ice), with dependent variables being y-balance measurements in the anterior (ANT), posteromedial (PM), and posterolateral (PL) reach direction along with COP velocity movements. The dependent variable of y-balance test reach distance was measured in centimeters (cm) and normalized to leg length distance. COP velocity was measured in centimeters per second for anterior posterior (AP) and mediolateral (ML) directions.

Instruments

We used a conductive force plate (BP400600, AMTI, Watertown, MA) to measure subjects' Center of Pressure during y-balance motions. Displacements were measured along x-axis and y-axis.

We used an industrial digital thermometer (Thomas Traceable Kangaroo, Philadelphia, PA) to measure CWI container temperature. This was performed in order to ensure cold-water application was consistent throughout the study.

The container used for CWI was a field-made container that was filled to approximately 60% ice and 40% water.[2] Level of ice was standardized to approximately the height of the subject's proximal fibular head.

Testing Procedures

Subjects reported to the laboratory on two separate days (CWI and control day) dressed in shorts and T-shirt. Subjects were required to be defined as recreationally active to participate in the study. In this study, recreationally active individuals were defined as exercising aerobically and anaerobically 1 to 3 times a week at a low-to-moderate intensity[14]. On the first day, subjects were screened to determine their ability to participate in the study. The screening consisted of subjects completing the health history questionnaire and ensuring they had no lower extremity injury in the past 6 months. Subjects then signed the IRB consent document before they were randomly assigned to a treatment order (CWI or no CWI). Treatment order was established by having subjects select a piece of paper from a container indicating what they would receive on the first and second day of data collection.

Subjects were then screened to determine if they had a cold hypersensitivity. If subjects did not display any cold allergy or other abnormal skin reactions, they were asked to stand to measure height in centimeters and then asked to lay supine on a plinth table to measure leg length. Leg length was measured using a tape measure from the anterior superior iliac spine to the center of the ipsilateral medial malleolus.[15]

Subjects were then asked to position themselves on an elevated chair with their shoes and socks removed. A surface thermometer was secured on the inside of the CWI container that measured degrees Celsius. A temperature range from 0°-5° C was maintained during treatment. The thermometer was secured using surgical tape inside of the container. The CWI container was approximately filled with a ratio of 6:4 ice to water, to ensure proper cryotherapy application during the treatment[2]. On the day in which subjects were assigned to receive the CWI, we prepared the subjects by seating them on a chair. The subject's leg was measured accordingly to ensure that the water level would reach the required height of the proximal fibular head. When prepared, the subject's leg was submerged for a 10- to 15-minute application period and when subject reported complete numbness.[1,2] During treatment of the modality, every minute, the subject was asked to lift his/her leg to create minor moment of the fluid. This was performed to prevent any thermal gradient forming during modality application. Also, during each minute of displacing the thermal gradient, the temperature of the fluid was recorded to ensure a consistent temperature of treatment among subjects[2]. Following application, the subject lifted his/her leg out of the CWI container and placed it onto a dry towel. The subject had 30 seconds from application of CWI to dry the lower extremity completely and prepare for the y-balance test. For the control group, subjects were able to perform the same y-balance protocol with the standardized rest periods between reach directions.

During the performance of the y-balance test protocol, subjects were asked between each period of reach direction to report if the treated ankle was still considered "numb". In the event that subjects reported no more numbness in the treated ankle, data collection was ceased and subjects were asked to return to the CWI container. The subject's ankle was placed back in the container with the investigator ensuring again that the water level remained consistent to the original treatment. The same protocol that was performed during the initial treatment of cryotherapy was kept consistent with the exception of the length of treatment. Subjects were required to place their ankle in the CWI container for a minimum of 5 minutes and with self-reported numbness.[1,2,16] When the two conditions were met by the re-application of CWI, the subjects were then given 30 seconds again to dry their ankle and return to the testing area to continue data collection. Subjects were asked again after their reach distance to report "numbness" in the ankle that may have subsided and if needed, the subject would again place their ankle back into the CWI container following the same protocol.

Y-Balance Test Protocol

Due to past research, the y-balance directional movements used were anterior (ANT), posteromedial (PM) and posterolateral (PL).[15,17,18] The procedure of measurement for these reach directions is comparable to the Star Excursion Balance test. This method is considered reliable with literature reporting moderate to good intratester reliability in studies with ICC of (0.67-0.96).[19-21]

Once subjects completed the consent and health history questionnaire, they were provided orientation on the proper technique of the y-balance test. Prior to CWI, subjects were shown by the data collector how to properly perform the y-balance test. Once completed, subjects were allowed to have four nonrecorded practice trials in each direction[18]. During testing, each subject was given three trials in each direction (with the highest reach direction saved). The leg tested was opposite of the subjects dominant leg (the leg they would use to kick a ball). During testing, the subject was instructed to perform each movement in a randomized order to prevent familiarization. Counterbalancing was controlled by utilizing a random number generator and assigning each direction a number (Anterior = 1, Posteromedial =2, Posterolateral = 3). Local fatigue was also controlled by maintaining consistent rest periods, with 10 seconds of rest provided between each reach attempt and 30 seconds of rest when switching between reach directions. These periods were established to minimize cryotherapy loss. Participants stood on the force plate with the center of the foot placed at the designated marker on the force plate to ensure proper measurement of COP. To measure the distance of the y-balance, a 1.5-meter measuring tape was used in each direction in order to measure accurate distance scores in centimeters.

Due to the fact that an increased leg length results in a greater distance reached,[15,18] leg length was normalized for each distance reached for a subject. In order to achieve normalization, reach distance was divided by subject's leg length as measured from anterior-superior iliac spine to medial malleolus, and then multiplied by one hundred. These values were interpreted as a percentage of reach distance in relation to the participant's leg length.[15]

During measurement of y-balance, a trial was omitted if subjects removed their hands from hips, placed excessive weight on reach foot, did not return to starting position, or did not touch down on tape measure. If the subject lost balance or was not able to maintain single-leg balance, the trial was unsuccessful and an additional trial would be required.

Kinematic Analysis

The maximal reach distance (cm) from each direction (ANT, PM, PL) was measured by recording the point where the most distal part of the foot reached. These measures were then normalized to each participant's leg length for comparison.

Kinetic Analysis

COP excursions in the medial-lateral (ML) and anterior-posterior (AP) directions was recorded during the y-balance testing. Displacements were measured along the x-and y-axis during each trial. The COP excursions were calculated from the horizontal moment in the x- and y-axes and vertical force data generated from the force plate. COP means velocity were calculated by dividing the COP mean excursion by time. The reliability for means velocity squared via a force plate are related to having a high reliability in the A/P (R=0.86) and M/L (R=0.81) directions.[22]

Statistical Analysis

All statistical analyses were performed using a specialized statistical software package (SPSS for Windows version 22.0, SPSS, Chicago, IL, USA). Means ± standard error calculated for each variable for each condition. Dependent variables were then compared using a repeated measure analysis of variance (RMANOVA). Effect-size statistics were calculated utilizing Cohen's *d* ranging from 0.20-0.49 indicating poor effect, 0.50-0.79 indicating moderate effect, and >0.80 indicating strong effect size[23]. Alpha was set a priori at ≤ 0.05.

RESULTS

The means and standard deviations for the subject characteristics are presented in Table 1. All Means and Standard Errors are reported in Table 2. Table 3 contains the repeated-measures univariate ANOVA for COP and normalized reach distance. There was no significant within-subject interaction on all variables [Wilks' Λ=0.70, F(df) = 0.999, p = 0.471]. ANT Reach presented as closest to significance and largest effect size [F(df) = 2.51, p = 0.123, effect size = 0.33]. Figure 1 illustrates a graph of pre- and post-normalized reach measures including standard error.

Table 1: Subject Demographics

	Age	Height(cm)	Weight (kg)
Mean	23.93	172.75	155.83
Median	24	173.2	159
Mode	23	173[a]	160
Std. Deviation	1.574	8.078	28.316
Minimum	21	157	110
Maximum	27	194	210

Table 2: Reach Values and COP Values

Reach Direction	F-Value	P	Effect size
ANT Y Axis	0.537	0.470	0.109
ANT X Axis	0.690	0.413	0.127
ANT Reach	2.517	0.123	0.335
PM Y Axis	0.688	0.414	0.126
PM X Axis	0.357	0.555	0.089
PM Reach	1.537	0.225	0.224
PL Y Axis	0.164	0.689	0.068
PL X Axis	0.487	0.491	0.104
PL Reach	0.007	0.936	0.051

*X and Y axis calculated by means velocity squared. Reach distance normalized by leg length.

Table 3: Reach Distance

Measure	Treatment	Mean	Std. Error	Confidence Interval	
ANT Y Axis	CON	9.444	0.968	7.464	11.423
	CWI	8.968	0.660	7.617	10.318
ANT X Axis	CON	15.107	1.590	11.855	18.359
	CWI	14.293	1.087	12.070	16.516
ANT Reach	CON	84.645	1.132	82.330	86.960
	CWI	83.684	1.218	81.193	86.174
PM Y Axis	CON	7.866	0.769	6.293	9.439
	CWI	7.574	0.665	6.213	8.934
PM X Axis	CON	12.022	1.201	9.566	14.478
	CWI	11.719	1.056	9.559	13.878
PM Reach	CON	96.712	2.057	92.505	100.919
	CWI	95.493	2.066	91.267	99.719
PL Y Axis	CON	7.388	0.613	6.134	8.642
	CWI	7.552	0.627	6.270	8.834
PL X Axis	CON	11.320	1.004	9.267	13.373
	CWI	11.754	0.981	9.747	13.762
PL Reach	CON	102.601	1.900	98.715	106.486
	CWI	102.657	1.815	98.946	106.369

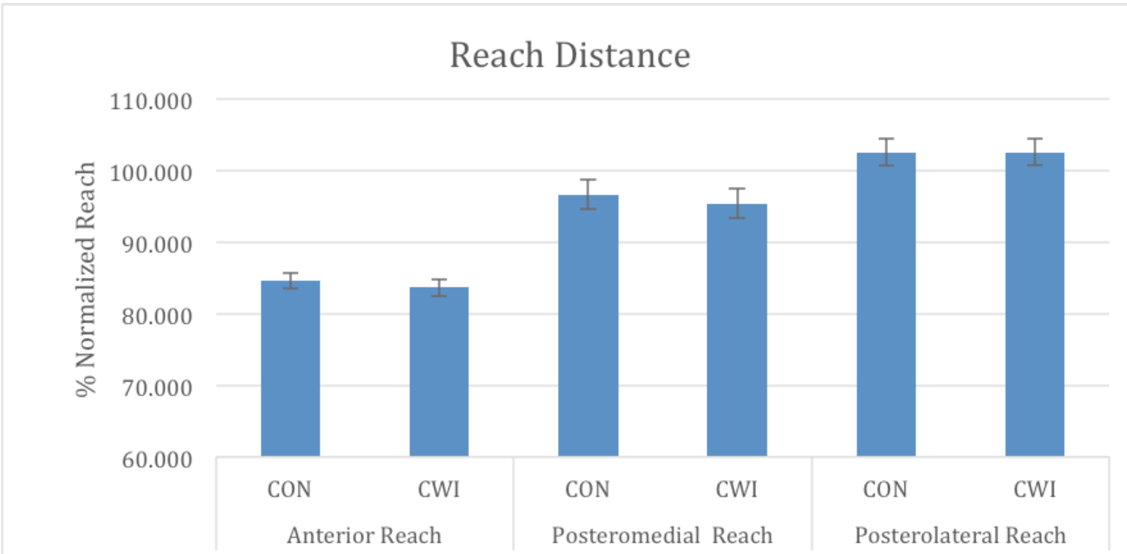

Figure 1: Normalized reach distance

DISCUSSION

We hypothesized that Cold-Water-Immersion (CWI) would not produce any significant difference in the performance of a y-balance test or in Center of Pressure (COP) sway. Our observations were conclusive in that application of CWI does not influence the performance of y-balance and COP sway.

Cold-water immersion is a commonly used modality in the acute care setting, specifically in the instance of ankle sprains.[2,3,9] The form of rehabilitation known as cryotherapy is thought to minimize the negative effects of inflammation while providing the numbing effect to pain at the ankle.[2 4] Typically, exercises are prescribed in the post-acute setting. However, with cryokinetics, an athlete may be able to perform more rehabilitative dynamic balance exercises earlier in the sub-acute setting.[4,5,8,24,25]

Dynamic balance exercises are a frequently used form of rehabilitation for an athlete in a return to play program.[8,17,26-28] The y-balance is commonly used to assess an athletes ability to perform a dynamic balance task and is used as a consideration when assessing an athlete's return to play.[7,19,21,29] When an ankle is injured during activity, it can immediately hinder a patient's ability to perform daily activities.[3] It is documented that when ankle sprains are graded as mild or moderate, the introduction of functional-based rehabilitation is more effective than the traditional immobilization method.[3,30] It does not appear that causing a lower extremity to become numb will influence a significant negative relationship between limb extremities that are not numb. This allows for a more functional rehabilitative program to be introduced early in the healing process, minimizing the negative effects of immobilization commonly seen in acute ankle sprains.

The results presented in this study conflict with Fullam et al. and Montgomery et al. and their results which state, there was a significant difference between the application of cryotherapy and the performance of a dynamic balance task. Fullam et al. reported a decrease in COP and Y-balance distance.[8] An explanation of this may be due to the lack of counterbalancing in the treatment and control groups. Subjects performed the same task twice in one day with no standardized rest period. Our study required a complete 24-hour rest period and ensured that the subject did not exercise moderately to strenuously 12 hours prior to the testing. On the other hand, Montgomery et al. found a significant difference in numbness in the lower extremity but only in treatment of the complete hip. When subjects performed the same task with the ankle and knee treated compared to control, there was no significant difference reported.[12]

Douglas et al. reported no difference in a static balance task performed but when asked to perform the task on an uneven surface (tilt board), COP measurements significantly decreased. This may be in part due to the uneven surface with additional perturbation forces.[11] In our study, the modified y-balance was used for the static position of the ankle while the subject moved dynamically.

These results are consistent with Thieme et al. with the relationship of cryotherapy's influence on proprioception at the knee.[13] Even when subjects self-reported an increase in difficulty to maintain balance along with dynamic performance, there was no statistical difference in performance between treatment and control.

There is much ambiguity in reference to cryotherapy and its influence of joint position sense.[31] Compared to the shoulder, the ankle appears to have a much stronger ability to maintain joint position sense along with dynamic balance task,[32] whereas the knee appears to have the least impact from a cryotherapy treatment when evaluating proprioception.[13] An explanation of this may be due to the superficial structures of the shoulder that may be more influenced by the cryotherapy application compared to the ankle or knee. Another explanation may be that the closed kinetic chain action of the y-balance provides more feedback to the joint, compared to an open kinetic action with the shoulder. Minimal evidence is available when explaining the influence cryotherapy has on joint position sense among varying joints of the body.

Cryotherapy may minimize the damage or influence it has on the mechanoreceptors. [33] The damaged mechanoreceptors are known to have an influence on balance deficits in those with instability after an ankle sprain.[25] A study performed by Khin-Mylo et al. revealed that patients with a history of chronic ankle instability had a delayed peroneal muscle activation when asked to perform a dynamic task, but, when injected with local anesthetic, participants' senses of stability increased and muscle reaction time decreased.[34] This study supports the theory that the sensory numbing of an ankle does not affect ankle stability. An explanation of this may relate to the mechanism of the stretch reflex.[35] When an afferent neuron excitation travels to an alpha motor neuron, the excitation of a gamma motor neuron induces a contraction. When an ankle sprain occurs, literature has identified that the lesions can be located at the superficial peroneal nerves but not the deep peroneal nerves.[36] The influence of these lesions may cause an interruption in mechanoreceptor excitability, which decreases the reaction time and stabilizing muscle reaction time.[34] However, this does not explain our findings and the cause of our uninjured subject population and the lack significance in COP and y-balance performance.

There are some limitations in this study; the results reflected may not properly represent those affected by acute ankle sprains being that the sample studied was to represent an uninjured population. Another limitation is the self-reported numbness by the participant. Since time will influence the degree of numbness, it would not have been realistic to objectively test for numbness at the ankle, without sacrificing important time used for measurement in y-balance performance. Another limitation is each participant may have a different subjective opinion on the definition of complete numbness at the lower extremity. What some participants may have classified as completely numb for one individual may be different for another. The final limitation is the length of treatment applied to the ankle joint. Though the range of application of CWI was between 10-15 minutes, this treatment range may not be consistent with varying extremity joints such as a knee or shoulder.

Implications for Clinical Practice

In conclusion, Cold-Water-Immersion does not appear to have significant influence on the performance of dynamic balance task at the lower extremities. This may allow clinical practitioners to introduce more dynamic balance and rehabilitative exercises earlier in the postacute injury setting. However, future studies should evaluate cryotherapy's ability to treat subacute ankles in the clinical setting and evaluate the return to play progress of individuals in the clinical setting.

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