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Effects of cold application on isometric strength and endurance of quadriceps femoris muscle

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Summary

This study was carried out to investigate the effect of cold therapy on isometric strength and endurance of the quadriceps femoris muscle group. Sixty volunteer healthy normal subjects participated in the study, 30 were males and 30 were females. They were aged between 20 and 27 years. The subjects were screened for previous knee injuries or abnormalities through history taking and physical examination. The baseline isometric strength and endurance of the quadriceps was tested before application of cold on the thigh. Immediate post and 10-minute post cold application isometric strength and endurance were measured using an adapted cable tensiometer. The result of the study showed that cold increased the isometric strength of the quadriceps in all the subjects immediate post and 10-minute post cold application *($P < 0.05$)* and the immediate post cooling endurance index of male and combined male and female subjects *($P < 0.05$)*. No significant increase was seen in the immediate post cooling endurance for female subjects ($P > 0.05$). Also no significant difference was seen in 10-minute post cooling endurance of all the subjects when compared with the pre-cooling endurance. This study therefore concluded that cold application increased isometric muscle strength and endurance post cold application. It was therefore recommended that application of cold on muscle should be employed while rehabilitating an individual with musculoskeletal pathology or deficit particularly while training for muscle endurance, strength and restoration of muscle function.

Keywords: *Cryotherapy, isometric strength, endurance.*

Résumé

Cette etude a ete fait four investiguer l' effet de la therapic froide our la force isometrique et l' andurance des groupe de muscle quodriceps femoral. 60 voluntiers en bonne rante ont participes a' cette etude, 30 etaient des males et 30 etaient des females. Its ETAINET dans la tranche d'age dentre 20 et 27 ans. Its nvaient ete examine's pour les blessures fassles aunc genous or pour des anomalies apres l'histhorique of e'examen physique. La force isomerique debase et e'endurance des quadriceps a ete teste avont l' application de la glace zur la cusse. Immedialement apres et 10 minutes apres l'application de lo glace la force isomerique et l;endurance evient ete mesres avecure cable tensiometres adapte. Le resulted de e'etude a montre que le froid augen te la force isometrique de quatriceps chez tous les sujets immediatement apres et 10 minutes apres la therapeutique froide *($P<0.05$)*, L indice de l' endurance immediatement apres froid et chez les males et celle des males of females combines *($P<0.05$)*. Aucune augmentation significative n'avait ete absciolue immediatement apres la glace en endurance chez females ($P<0,05$) et aurzi il n'yavait pas de difference en endurance 10 minutes apres la glace chez tous les sujets comparativement as el endurance avaint le froid. Cette etude parconcequent condu que l'application la therapeutique froide augmente la forie isometrique demuscle et l' endurance apres son applications. It est lependant recommande que e'lopplication du froid zur fe muscle doit etre excecute pendant la rehabit eitation des patients ayont une pathologie. misculo siceletales or un deficit particulier pendant eletrainment de l'endurance des muscle, la force et la restoration de laforation des muscle.

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Introduction

Resisted exercises, strength testing and training of the knee extension muscles are frequently performed procedures in physical therapy. Strength testing is a mode of assessment influenced by a broad spectrum of anatomical, physiological, mechanical and methodological considerations [1]. The determination of maximal isometric strength and endurance index of knee extensors provides an objective means of quantifying the resistance against which the muscles work. Analysing the sustained endurance of muscular responses serves as an adjunct to the traditional strength test.

In the general clinical practice of physiotherapy, whether it is in a hospital based or community based delivery of health care to patients, cold therapy is one of the frequently used modalities. In recent years, the application of cold therapy has been on the increase in physiotherapy procedures. Observed clinical effects of application of cold include pain relief, reduction of swelling, improved circulation, increase in joint range of motior and decrease in spasticity with improved voluntary muscle action [2].

While there is a need to put the various physiotherapy modalities into maximum use, the physiological effect of one physiotherapy modality on the other when they are applied on the same patient within the same treatment session is also noteworthy. These considerations constituted the major motivation for this study. This study was therefore designed to find out the effects of local application of cold therapy on the maximal isometric strength and endurance index of the quadricep femoris muscles.

Materials and methods

Sixty clinical students of the College of Medicine, University of Ibadan, participated in this study. The subjects whose ages ranged between 20 and 27 years were made up of 30 female and 30 male volunteers. Each subject was screened for previous knee injuries or abnormalities through history taking and physical examination. The procedures of this study were adequately explained to the subjects. Informed consent was sought and obtained from the subjects.

The following materials were used for the study:

1. An adapted cable tensiometer (ACT) made from a spring balance was used to measure the quadriceps muscle strength [3].
2. Goniometer: A simple, double-armed half- circle protractor type of goniometer was used to measure the starting position angle of the knee joint before each quadriceps strength and endurance measurement.
3. A specially designed high testing table with back rest at an angle of 120 degrees.

4. A mercury -in-glass thermometer calibrated from - 10 °C to 110°C was used to measure the cold water temperature. A second thermometer, an alcohol-in-glass thermometer, calibrated from -3 °C to 5 °C was used to measure the room temperature.
5 Crushed ice added to water in a proportion of two parts of ice to one part of water to provide the required source of therapeutic cooling. The temperature of the ice-water mixture was kept within the range of 3 °C and 6 °C.
6 Liquid paraffin to protect the skin against ice burn.
7. Ice-towel for cold application was prepared by immersing a 1m x 0.5m terry towel in the ice-water mixture. Water was sequeezed out such that ice-chips clung to the towel which was then folded into eight layers for use.

The age, height and weight of each subject was recorded on the resting day. Subject wore a simple vest and a pair of shorts for easy assess to the thigh. Subject sat on high testing table, the back rest had a cushion pad, the sitting platform was well padded to provide comfort [4] and also prevent subject's buttocks from sliding on the table. The subject was instructed to hold the side edges of the testing table in order to give maximal extensor strength on the knee. The knee joint was positioned at an angle of 60° flexion [5].

An ankle sling was wrapped round the subject's ankle and attached to the adapted cable tensiometer (ACT). The other end of the ACT was anchored to the lower end of the testing table. The subject was instructed to pull on the ACT by extending his knee to the fullest possible range. The maximal pull on the ACT was recorded as the value for the maximum strength, the time elapsed for the pull to fall to half the maximum value was recorded as the endurance index [6]. This procedure was repeated twice at 10 minute interval to allow for recovery from fatigue. The obtained values after these trials were recorded as the baseline values

The integrity of the thermal skin sensation on the enterior aspect of the subject's right thigh was determined by his ability to discriminate between the temperatures of a hot and a cold test tube placed on the skin during thermal skin sensation test. Only subjects with intact thermal skin sensation proceeded with the study. Prior to the cooling, a thin film of liquid paraffin was lightly applied on the exterior aspect of the thigh as a precaution against ice-burn. Ice-towel at a core temperature of between 3 and 6 °C was applied on the anterior aspect of the subject's thigh over the entire quadriceps femoris muscle for a duration of five minutes. Ice towel technique was used in preference to the immersion and ice-cube message technique because it was the most appropriate technique to give uniform cooling which could be localized to the quadriceps femoris muscle. The cooling time did not exceed five minutes in order to ensure optimum cooling before the ice chips melted and the towel became warmer. Using earlier described measurement procedures, muscle strength and endurance index were measured and recorded immediately post cooling and at 10-minute post cooling interval.

Treatment of data

Descriptive statistics of mean and standard deviation were computed for all the measured variables. Paired t-test was used to see the differences between the pre- and post cooling values for the subjects. The alpha level was set at the 0.05.

Results

A total number of 60 subjects (30 males and 30 females) participated in this study. The physical characteristics of the subjects were as shown in table 1. The mean pre-cooling and

Table 1: Physical characterisitic of the subjects

Physical variable	n = 30 Male subject X"S.D	n = 30 Female subject X"S.D	n = 60 All subject X"S.D.
Age (Yrs)	23.43"1.89	22.63"1.71	23.03"1.83
Weight (kg)	60.75"6.80	53.40"8.78	57.07"8.63
Height (cm)	171.23"11.95	161.18"7.20	166.21"11.02

the immediate post-cooling the subjects were as shown in Table 2. There were significant differences in the pre-cooling and immediate post- cooling muscle strength of each group of subjects *(P < 0.05)*. The mean 10-minute post- cooling muscle strength of the males, females and combined males and females were 50.16"7.6 kgf, 32.80"8.98 kgf and 41.50 " 12.02 kgf, respectively. Student's (paired) t-test analysis revealed significant differences in the mean pre-cooling muscle strength and 10-minute post-cooling muscle strength for the male, female and combined male and female subjects. No significant difference existed between immediate and 10-minute post-cooling muscle strength for the male subjects

Table 2: Mean pre-cooling, immediate post cooling and 10-minute post cooling maximal isometric strength.

	PMS (kgf)	IPMS (kgf)	t-value	PMS (kgf)	IOPMS (kgf)	t-value	IPMS (kgf)	IOPMS (kgf)	t-value
Male (n = 30)	46.20"6.60	51.57"7.72	3.77*	46.20"6.60	50.16"7.60	3.68*	51.57"7.72	50.16"7.60	1.407
Female (n = 30)	29.25"7.58	35.67"8.46	8.123*	29.25"7.58	32.80"8.90	3.72*	35.67"8.46	32.80"8.90	4.66*
Combined (n = 30)	37.73"11.08	43.62"11.35	9.68*	37.73"11.08	41.50"12.02	5.27*	43.62"11.35	41.50"12.02	3.61*

Key
PMS = Pre-cooling muscle strength
IMPS = Immediate post-cooling muscle strength
IOPMS = 10-minute post-cooling muscle strength
* = *Significant*

Table 3: Mean pre-cooling, immediate post-cooling and 10-minute post-cooling endurance index of the subjects

	PEI (seconds)	IPEI (seconds)	t-value	PEI (seconds)	IOPEI (seconds)	t-value	PEI (seconds)	IOPEI (seconds)	t-value
Male (n = 30)	30.88"9.82	34.96"9.80	2.160	30.88"9.82	33.72"12.03	1.289	30.88"9.82	33.72"12.0	0.810
Female (n = 30)	26.74"11.03	27.99"11.16	0.702	26.74"11.08	29.35"10.11	1.153	25.49"11.80	29.42"10.1	0.755
Combined (n = 60)	28.81"10.56	31.51"11.08	2.05	28.81"10.56	31.57"11.23	1.74	28.81"10.56	31.57"11.23	0.47

Key
PEI = Pre-cooling endurance index
IPEI = Immediate post-cooling endurance index
IOPEI = 10- minute post-cooling endurance index

($P > 0.05$) while t-test analysis showed significant difference between immediate and 10-minute post cooling strength in the females group and in the combined males and females group (Table 2)

The pre-cooling and immediate post-cooling endurance indices for the subjects were as shown in Table 3. There were significant differences *($P < 0.05$)* in the pre and immediate post cooling endurance index of male subjects and combined male and female subjects while no significance difference existed between the pre and immediate post-cooling endurance indices of the female subjects *($P > 0.05$)*. Ten minute post-cooling endurance index for the male, females and combined subjects were 33-72 " 12.03, 29.35 " 10.11 and 31.57" 11.23 seconds, respectively. No significant differences existed between pre-cooling and 10-minute post-cooling values for each of the groups *($P > 0.05$)*. There was no significant difference *($P > 0.05$)* in the immediate and 10-minute post-cooling endurance index of the males, females and combined subjects (Table 3).

Discussion

This study showed that there was significant difference in the pre- and immediate post-cooling maximal isometric strength of the quadriceps muscle group. A significant increase in isometric strength was also observed 10-minute post cooling compared to the pre-cooling value. The result of this study is in agreement with the submission of a previous study [7]. Cold reduces the local temperature of muscle and physiological responses of cold include vasoconstriction followed by immediate vasodilatation. The alternate constriction and dilatation of blood vessels improves blood supply to the muscle with accompanying increase in oxygen and nutrients. The increased nutrient supply may be responsible for the increased strength of the quadriceps after application of the cold.

The immediate post-cooling endurance index of quadriceps femoris was significantly higher than the pre-cooling endurance index for male and the combined subjects. There was no significant difference between the pre- and immediate post-cooling endurance index of the female subjects. It has been reported that water bath at 26 °C gave maximal endurance index in quadriceps femoris following immersion of the test leg in water at 12 °C, 26 °C or 11 °C for 45 minutes [8]. However this present study demonstrated that with an application of ice-water mixture at temperatures of between 3 °C and 6 °C to the quadriceps muscle, the endurance index increased immediately post-cooling.However, no significant difference was found in endurance index of the quadriceps 10-minute post cooling. The observed significant difference in isometric strength of quadriceps pre- and post- cooling and endurance index pre- and immediate post cooling may be as a result of facilitatory effect on the alpha motor neurone pool, at least in the short term and sympathetic system stimulation which had been suggested as the 2 mechanisms causing greater immediate muscle strength following local cooling [9].

An increase in isometric muscle strength of a muscle undergoing a recovery from reduced intra-muscular temperature following cold immersion of the parts involved has been reported [8]. These researchers found that the peak value of the isometric strength occurred when corresponding intra-muscular temperature was around 32.6 °C.

Conclusion

The results of this study showed that cold has a significantly positive effect on maximal isometric strength and endurance index of quadriceps femoris muscle. It caused a significant increase in muscle strength and endurance. It is recommended, therefore, that application of cold on muscles should be employed while rehabilitating a patient with musculoskeletal pathology or deficit, particularly while training for muscle strength, endurance or when training for restoration of muscle function.

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