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RESEARCH ARTICLE

Effect of temperature on muscle endurance in healthy adults

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ABSTRACT

Background: The local application of cold or heat on the muscle is known to affect the muscle endurance which can be measured using the handgrip dynamometer. **Aims and Objectives:** The present study has been done with the objective of studying the effects of cold water immersion and rewarming on the endurance of the hand and forearm muscles. **Materials and Methods:** The study included 40 healthy medical students. The dominant hand and forearm were immersed in cold water for 5 min after which muscle endurance was determined using the handgrip spring-type dynamometer and this was followed by immersion of hand and forearm in hot water after which muscle endurance was again determined. Paired *t*-test was used to analyze the data. **Results:** On comparing the muscle endurance after cold water immersion and rewarming, the results showed that there was a statistically significant improvement ($P < 0.05$) in the muscle endurance after rewarming. **Conclusion:** The results demonstrate an increase in the hand and forearm muscle endurance after rewarming which may be beneficial for people working in meat packaging and cold storage industries. These industrial workers can immerse their hands in rewarming sinks intermittently which might enhance their work performance.

KEY WORDS: Endurance; Handgrip Dynamometer; Effects of Temperature

INTRODUCTION

Changing the temperature of the muscles is widely used as a therapeutic procedure.[1] When the muscle temperature is increased, it enhances the oxygen supply to the muscle which improves the muscle function.[2] Increasing muscle temperature affects the muscle contractility which includes the rate of force that is produced and the velocity of contraction.[3]

When the muscle temperature is decreased by local application of cold, the body tries to conserve heat by vasoconstriction.[4] It has also been shown that the local application of cold decreases the motor nerve conduction velocity and causes an inefficiency of the musculotendinous unit.[5]

The effects of temperature on manual dexterity, reaction time, and optimum grip span showed that performance was significantly lower at low temperatures compared to performance at higher temperature.[6] The present study has been done with the objective of studying the effects of cold water immersion and rewarming on the endurance of the hand and forearm muscles using the handgrip spring-type dynamometer at normal room temperature.

MATERIALS AND METHODS

After obtaining institutional ethical committee clearance, the study was conducted on 40 young healthy medical students with a normal body mass index (BMI) and aged between 18 and 20 years comprising 20 male and 20 female subjects. Each subject was explained the purpose and the procedure of this study after which a written informed consent was taken.

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Subjects involved in sports or gym activity which might influence handgrip strength were excluded from the study.

The muscle endurance was determined using the isometric handgrip spring dynamometer. The subjects were given a practical demonstration on how to use the handgrip dynamometer and were asked to use it on a trial basis. After a rest of 10 min, the grip strength was assessed by asking the subject to compress the handle with maximum effort. This was done 3 times with a gap of 1 min between each trial and the maximum value was considered as their T_{max} (maximal isometric tension). The hand endurance was then assessed for 60% of the T_{max} with the subjects being asked to hold the contraction at this value for as long as they could hold it[7] and the time duration was noted using a stopwatch. After 10 min, the subjects were asked to dip their dominant hand and forearm up to elbow in cold water (5°) for 5 min and then immediately were asked to compress the handgrip dynamometer for 60% of T_{max} till they could no longer hold the contraction (onset of fatigue), and the duration was recorded following which they were asked to immerse their hand and forearm in warm water (40°) for 5 min and the muscle endurance was again recorded.

Statistical Analysis

Statistical analysis of the data was done using the Statistical Package for the Social Sciences (SPSS) version 17.0 and *P*-value was taken as statistically significant at 5% confidence level ($P < 0.05$). Paired *t*-test was used to analyze the data.

RESULTS

Demographic and descriptive statistics are described in Tables 1 and 2. Analysis of the data [Table 3] showed that there was a statistically significant increase ($P < 0.05$) in the endurance time after rewarming (40°C) following the cold water hand and forearm immersion.

DISCUSSION

Muscle function is sensitive to temperature and the objective of the present study was to find out if rewarming can improve the muscle endurance after cold water immersion. In the present study, the demographic statistics [Table 1] of the subjects were well balanced and did not vary significantly in factors such as age and BMI which have been shown to affect the grip strength.[8-10] Mean endurance time – after cold water immersion was 27.77 s compared to 34.42 s after rewarming [Table 2]. Statistical analysis of the data [Table 3] demonstrates a statistically significant increase in the mean muscle endurance by 6.65 s ($P = 0.000$) after rewarming. This indicates that muscle endurance improves after rewarming which may indicate that rewarming can increase muscle performance in workers employed in cold storage factories. Decrease in muscle temperature causes vasoconstriction[4] and decreases the motor nerve conduction velocity,[5] and increase in muscle temperature increases the blood flow and enhances the muscle function[11] which may be the reason for the results of the present study in which there was a statistically significant improvement in hand and forearm endurance after rewarming.

Table 1: Demographic statistics

Demographic factors	*n*	Mean±SD
Age	40	18.42±0.675
BMI	40	21.49±1.36

BMI: Body mass index, SD: Standard deviation

Table 2: Descriptive statistics

Descriptive factors	*n* (number of subjects)	Mean±SD
Maximum strength (Kgs)	40	28.90±7.81
Onset of fatigue (Kgs)	40	17.50±4.86
Endurance time – before cold water immersion (S)	40	50.82±27.73
Endurance time – after cold water immersion (S)	40	27.77±16.87
Endurance time after rewarming (S)	40	34.42±15.16

Table 3: Comparison of muscle endurance after cold water immersion and rewarming

Descriptive statistics	Mean±SD	*t*	*P* value
Comparison of muscle endurance after cold water immersion and rewarming	6.65±9.186	4.578	0.000

This result is consistent with the results of many previously published studies. Effects of heat and cold application on isometric muscular strength were studied by Barnes[11] and their study showed that muscle strength was significantly increased after heat application. Similar study was conducted by Chastain[12] where they studied the effect of deep heat on isometric strength and their interpretation showed that muscle strength was improved after application of deep heat to the muscle Davies and Young[13] studied the effects of temperature on the contractile properties and muscle power of triceps surae in humans. This study showed increase in triceps muscle power after application of heat. The effect of actively increasing muscle temperature on grip strength was studied by King *et al*.[14] and they demonstrated increase in grip strength after application of heat. A study by Nodehi-Moghadam *et al*.[15] which showed that locally applied hot pack on the forearm increases the wrist flexor muscle endurance and application of ice pack decreases the wrist flexor muscle endurance compared with the normal grip endurance tested on different days. However, our study compared the muscle endurance after cooling with the endurance immediately

after hand rewarming by submersing the dominant hand and forearm.

The strengths of the study were most of the factors which affect the muscle endurance like age, sex, BMI were well balanced among the subjects. There were limitations in our study such as the study was done at normal room temperatures and the effect of cold room temperatures was not studied, no gloves were used by the subjects and the muscle temperature after cooling or heating could not be determined. Many factors which influence the force of contraction of muscle like serum electrolytes, blood glucose, hormone levels like thyroid, glucocorticoid levels were not measured among subjects. Alteration of these parameters may be present subclinically even though subjects were clinically healthy young adults.

CONCLUSION

In the present study, the results demonstrate a decrease in the muscle endurance after immersion of hand and forearm in cold water and an increase in the muscle endurance after rewarming. The results of the present study may be beneficial for people working in meat packaging and cold storage industries where the hands get exposed to cold temperatures. These industrial workers can immerse their hands in rewarming sinks intermittently while working which might increase their hand endurance and enhance their work performance.

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