

The effects of local heating and cooling of arm on maximal isometric force generated by the elbow flexor musculature in male subjects

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Objectives: It is well known that neuromuscular function is temperature sensitive. Changing of muscle temperature can effect voluntary muscle contraction. The aim of this study was to investigate the effects of cooling and heating on maximal isometric force generated by the elbow flexor musculature in male subjects

Methods: Forty five healthy males encompassing 3 groups participated in the current study. The maximal isometric forces of elbow flexion were measured before and after placing ice and hot packs over the arm for 15 minutes. Paired t tests were used to compare differences between pre and post maximal forces between groups

Results: The results showed no significant difference between pre and post maximal isometric force scores in control and heat groups ($P>0.05$) and significant difference between pre and post cooling maximal isometric force scores ($P=0.02$)

Conclusion: The results suggest that the use of 15 minutes cold pack over the arm can significantly increase muscle force, however, the use of hot pack had no change in force output

Key words: Elbow flexor muscles, temperature, muscle strength

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Introduction

Temperature is an important determinant of skeletal muscle function. Like most biological processes, skeletal muscle contraction is temperature sensitive (1). It has been known that important parameters like maximal isometric force production, the rates of force development and relaxation and maximal power production strongly depend on temperature (2). A greater muscle blood flow with elevation of intramuscular temperature would increase oxygen supply, thus potentially improving muscle function (1, 2). On the other hand, supply of energy and removing of metabolites and heat are potential limiting factors in force production. The rate of anaerobic glycolysis, via ATP hydrolysis, is highly temperature dependent in high intensity exercises. Increasing of muscle temperature may increase use of substrates and lead to accumulation of metabolites. It is also accepted that the exercise-induced hyperthermia, via increase core temperature, may lead to a reduction in physical performance. Some studies suggested that voluntary force

development during prolonged sub maximal contractions is reduced with hyperthermia, but data about the effect of local heating on brief maximal voluntary contraction are scarce (3, 4).

Cryotherapy is also a rehabilitation procedure following acute joint injuries. The body responds to cold stress with a vasoconstriction to maintain the core temperature. After a period of vasoconstriction a vasodilatation usually occurs. During cold – induced vasodilatation there is an increase in blood flow (5).

Reports of the effects of cold on neuromuscular function are not consistent. Some investigators have reported increases voluntary motor output following cryotherapy(6-9). However, other studies showed decreases or no change in voluntary muscle force following cryotherapy(10-12,5).

Physical therapists clinically use hot pack to decrease the muscle pain and spasm and to increase the extensibility of soft tissues; also, cold pack has been used for the treatment of acute musculoskeletal injuries. The relationship between local tissue

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temperature and isometric strength and the effects of the treatments of heating and/or cooling in sport activities and rehabilitation on the muscle are unclear. It was the purpose of this study to determine the effects of hot and cold packs on maximal isometric force generated by the elbow flexor musculature

Materials and Methods

Forty five healthy males encompassing 3 groups participated in the current study. All subjects were right handed with no history of resistance training, and no upper extremity pathology (9). The right elbow was examined. Before participating in the study, all subjects signed an informed consent form approved by the human subjects committee of University of Social Welfare and Rehabilitation Sciences. Physical characteristics of the subjects in each group are shown in Table 1.

The study consisted of a control experiment (control) and experiments with passive muscle heating (heat) and cooling (cool).

Cold and heat were applied over the anterior arm and elbow using ice and hot packs.

Skin temperatures of elbow were measured before and after muscle heating and cooling by a thermometer

In both groups, isometric peak force of the elbow flexion was measured at the beginning and after cooling and heating with a tensiometer (MIE Medical Research Ltd). All participants undertook a familiarization session. After a brief explanation of the testing procedures, participants were asked to execute three submaximal trials to familiarize themselves with the tests procedures. Test sessions were started with a five minutes warm up of arm stretching exercises. The subjects were seated in a chair, the trunk and non dominant arm were stabilized by straps. The leather strap of tensiometer was secured in the region of wrist region. The force generated by the elbow flexors was measured, when

the elbow was flexed. Subjects were verbally encouraged to maintain maximal effort while data were collected for 3 seconds. The mean of three repetitions of maximal isometric contraction was measured in kilogram (Kg). Following the base-line maximal isometric contraction in each group, hot or cold packs at approximately 40-42°C and 5-7°C were applied on the anterior aspect of arm for 15 minutes. Another set of measurements was performed immediately following the removal of the ice and cold packs.

Test-retest reliability of the tensiometer was determined in a pilot study prior to data collection by repeating the test procedure twice, conducted on one day, according to the methodology described above. Ten healthy subjects that were not included in the main study were recruited for reliability testing.

Data analysis

The data were analyzed using the SPSS statistical software version 16. The maximal isometric force values were collected in kilogram by the tensiometer. Means and standard deviations were calculated. The intra-class correlation coefficients (ICC) and standard error of measurement (SEM values) were used to assess intra-tester reliability of the measurement. We calculated the ICC (3, 1) as described by Shrout and Fleiss (13) because only one judge evaluated the same population of subjects. Paired t tests were performed to compare differences between pre and post maximal force in each group (control, heat, cold groups). The significance level was set at 0.05.

Results

There were no statistically significant difference in subjects' age (P=0.24), height (P=0.76) and weight (P=0.84) among the three groups.

Descriptive statistics for the measurement scores are presented in Table 1.

Table 1. Descriptive Statistics of measurements scores in the three groups

Variable (measurement unit)	control		heat		cold	
	mean	SD	mean	SD	Mean	SD
Age (year)	21.13	1.30	21.47	1.36	20.67	1.18
Height(Cm)	175.93	7.04	176.60	5.62	174.80	7.42
Weight(Kg)	65.20	4.89	65.93	5.59	66.40	6.15
Initial temperature (°C)	36.88	0.66	36.91	0.52	36.70	0.50
Secondary temperature(°C)	36.97	0.56	41.61	0.90	14.70	0.44
Primary maximal force (Kg)	22.24	3.42	21.76	2.70	21.81	3.29
Secondary maximal force (Kg)	22.58	3.72	22.41	3.15	23.09	3.24

ICC and SEM values for the measurements of maximal isometric force were 0.87 and 2.21 respectively.

The result of paired t tests showed no significant difference between pre and post maximal isometric

force scores in control and heat groups ($P>0.05$) and significant difference between pre and post cooling maximal isometric force scores ($P=0.02$) (Table 2).

Table 2. The results of paired t tests between primary and secondary maximal force in the three groups

group	mean	SD	Mean difference	t	P-value
Control initial force	22.24	3.24			
Control secondary force	22.58	3.72	-0.34	-0.93	0.37
Pre heat maximal force	21.76	2.69			
Post heat maximal force	22.41	3.15	-0.65	-1.54	0.02
Pre cold maximal force	21.81	3.29			
Post cold maximal force	23.09	3.24	-1.28	-2.77	0.15

Discussion

The results of this study showed that tissue temperature increased significantly when heated with a hot pack (4.64 degree).

If hot pack can increase muscle temperature it may be an effective method to improve muscle function. In this study the increase of maximal elbow flexors force after heating was low. No significant difference was found between pre and post heating maximal isometric force scores ($P>0.05$).

Previous studies have clarified that increasing muscle temperature by a general active warm up can increase the rate of force generation (2). Davies and Young reported that a muscle temperature increase of 2.5-3 degrees is optimal for muscle contraction, because it decreases muscle stiffness and improves the force velocity relationship, but in agreement with our results they did not find any significant differences in maximal voluntary contraction of triceps surae after heating (14).

We did not find any significant increase in maximal elbow flexion force because, the increase of intramuscular temperature with hot packs may have been relatively low. According to previous studies, significantly shorter endurance times were found for the heated muscles. It is accepted that the endurance time of sustained, sub maximal voluntary contractions was temperature dependent. Alterations of the rate of muscle metabolism and accumulation of metabolites may be at least partly responsible for muscle fatigue at high temperatures (3,5,15,16). The measurements of endurance time weren't included in this study.

Another result of our study was that, muscle cooling lead to significant increases of maximal elbow flexors force.

Cryotherapy is a therapeutic modality that is commonly used for rehabilitation of joint injuries and prior to athletic competition. Several authors

have reported that ice impairs physical performance and therefore increases the susceptibility of injury (10, 11).

De Ruiter et al. (17) reported that at low temperatures (22° C) maximal isometric force generated by human adductor pollicis muscle, rate of force development and the speed of muscle relaxation were reduced. It also has been shown that cooling of the skin could increase the recruitment of motor units. Thus repetitive work in the cold environment leads to higher electromyography activity and fatigue (17).

In agreement with our result Hopkins and Stenci (9) indicated that plantar flexion torque and soleus H-reflex increased following 30 minute joint cooling. It has been suggested that athletes could perform more exercises with less pain following joint cooling. This is partly due to decreased pain and facilitating motoneuron pools that may have been affected by the joint injury (18).

The body maintains the core temperature by vasoconstriction when exposed to cold environment. After a period of vasoconstriction a vasodilatation usually occurs. Cold -induced vasodilatation may lead to an increase in blood flow to muscles (5). Ducharme et al. (19) also showed higher blood circulation during cold -induced vasodilatation that may enhance motor function. It is shown that neuromuscular function is dependent on muscular temperature. Therefore, if cold -induced vasodilatation increases elbow flexor muscles temperature due to an increased blood flow to the extremity, this may have a beneficial effect on the neuromuscular function. The conflicting evidences observed in the literature may be due following two points:

First, the above-mentioned studies on human muscles have been made on either large proximal muscles or small distal muscles. Changing of temperature in large proximal muscles (like our

study) is difficult. High temperature variation evidently existed between surface and the muscle interior when exposed to hot or cold conditions, but, it was anticipated that intramuscular temperature of the small muscles (small hand muscles) would change easily.

Second, the effect of temperature on contractile properties of skeletal muscles has been examined in a number of mammals. Therefore, it is doubtful, if

the results can be compared directly with those obtained from small animal muscles (20).

Conclusion

The result showed no significant difference between pre and post maximal isometric force scores in control and heat group but the use of 15 minutes cold pack can significantly increase muscle force.

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