



## Original Article

## Effects of Temperature on Wrist Flexor Muscles Endurance

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## ABSTRACT

**Background:** It is widely recognized that neuromuscular function is temperature sensitive. Changes in muscle temperature may affect muscle force development. The aim of this study was to investigate the effects of temperature on wrist flexor muscles endurance.

**Methods:** Fifteen healthy subjects (mean age  $21.13 \pm 1.30$  years) participated in the present study. The wrist flexor muscles endurance was measured before and after applying ice and hot packs over the forearm for 15 minutes. Paired t tests were used to compare differences between pre and post intervention endurance.

**Results:** The results showed a significant increase in wrist flexor muscles endurance after heating. ( $P=0.04$ ). We also found that, cooling the forearm muscles led to significant decrease of wrist flexor muscles endurance ( $P=0.01$ ).

**Conclusion:** These results suggest that hand function is temperature sensitive. Therefore, further studies are needed to evaluate the effects of cold on muscular function in people working in workplaces with extreme temperature.

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## Introduction

Like many other biological factors, body temperature is known as an important indicator of muscles function. Increasing the muscle temperature affects the contractile characteristics of muscles including rate of force production and relaxation as well as contractile velocity [1]. It is claimed that increasing in the muscle temperature leads to augment the blood flow to the muscle. As a result more oxygen arrives to the muscle. This enhanced oxygen supply seems to be responsible for improvement in muscular function [1,2]. On the other hand, doing exercise in a hot environment has been shown to enhance core temperature and consequently, reduce muscles voluntary contraction. In addition, warming the whole body affects the blood flow to the central parts of the human body and lessens the dynamic training capacity and muscles endurance. Furthermore, it

may also impose an extra load to the cardiovascular system so as to meet the activated muscles biological needs [3,4]. The high temperature environment might altered motor units firing rate as well. It is happened by improving the rate of force development and relaxation in higher temperatures in comparison with lower temperatures [1,5,6]. Motor units firing rate is determined as a predictor for the amount of muscles force production. Therefore, the human body reduces its muscles force in order to protect the whole body from the probable injury of extra heating [4,6]. Nonetheless, heat is commonly used in physiotherapy and sport training to enhance muscular capability [6,7].

At the other extreme, there are people working and doing manual performance in cold environments. It was reported that the risk of shoulder, forearm and wrist injury were increased in such conditions. Exposing to the cold stress causes a vasoconstriction in the extremities in order to reduce core heat loss. This vasoconstriction also leads to decrease tissue temperature in the extremities and consequently, influence grip function, muscles coordination and nerve conduction velocity [7-12].

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The influences of low or high temperature on the muscle strength and cardiovascular system have been evaluated previously [1,4-7,13,14]. However, to the best of our knowledge there is no study to assess the effects of cold and heat on muscles endurance. Therefore, the purpose of the present study is to evaluate the effects of increase and decrease of the wrist flexor muscles temperature on their endurance in healthy individuals.

## Methods

Participants were recruited from the University of Social Welfare and Rehabilitation Sciences. The whole procedure was completely explained to them and they signed the informed consents prior to participating to the study. Participating in any regular sport or gym activity and any history of traumatic injury to upper extremities were recognized as exclusion criteria. Sport and gym activity considered as exclusion criteria to diminish any confounding effects of muscle tolerance to increase the temperature.

Participants were asked to sit on a chair, put their forearms on the armrest in a way that their elbows had 90 degrees of flexion and their forearms were supinated. Then they were supposed to flex their wrist with their maximal force. The procedure was performed three times and the average amount was considered as their maximal wrist flexor strength. After a 10 to 15 minute rest, participants performed a trial of wrist flexion with 20% - 30% of their maximal strength. They were instructed to hold the contraction as long as they could. The duration they could hold the contraction at the target level of strength was considered as wrist flexor endurance [6,7]. Then, a 40-42 degree hot pack was applied to palmar surface of participants' forearms for 15 minutes. Afterwards, wrist flexor muscle endurance was measured again.

With a 2-day wash out [13], the procedure was conducted again on the same participants. Although in the second session participants' forearms were exposed to an ice pack cooled in refrigerator temperature (0 centigrade degree). Before and immediately after the 15-minute ice application, wrist flexor muscle endurance was assessed.

A methodological study has been conducted prior to the main procedure to evaluate the intra examiner reliability for measuring the endurance of wrist flexor muscles in which the muscle endurance was measured two times, one day apart, prior to the performing the main study.

### Statistical Analysis

SPSS software version 16 was used For statistical analysis. The intraclass correlation of coefficient (ICC) and standard error of measurements (SEM) were calculated to determine relative and absolute reliability of the examiner in measuring the wrist flexor muscle endurance respectively [15]. Paired t-test were used to

investigate the effects of temperature on wrist flexor endurance. Level of significance was set at  $P < 0.05$ .

## Results

A total of 15 healthy male aged 20 to 30 years and right handed were participated in the study. The participants mean age was  $21.13 \pm 1.30$  years, mean weight  $65.20 \pm 4.89$  kilograms and mean height  $175.93 \pm 7.04$  centimeters.

The intra class correlation of coefficient and standard error of measurement for measurement of the muscle endurance were found to be 0.87 and 2.21 respectively.

The paired t-test revealed that applying hot pack induce a significant increase in the muscle endurance ( $P=0.01$ ) while the application of ice pack reduced the muscle endurance significantly ( $P=0.04$ ). The skin temperature improved significantly after heating, whereas decreased by cold pack ( $P < 0.001$ ).

Table 1 demonstrates means and standard deviations of wrist flexor muscles endurance at base line and after the application of hot or cold pack.

## Discussion

The results of the present study demonstrated a significant increase in wrist flexor muscles endurance after heating them.

Temperature is considered as an important determinant of muscles function. There are two theories which explain the effects of heating on muscles function. In the first view, it is assumed that increasing in muscles temperature lead to enhance muscles function due to more blood flow to the muscles. This theory has been developed based on the results of previous studies demonstrating an improve in dynamic training capacity followed by active or passive muscle warm up [6,7]. Contrary to this, the second theory explains the fact that doing exercises in a hot environment reduces dynamic training capacity due to general fatigue presumed as a result of core temperature increase.

Our results provide more evidence for the first theory. We applied a hot pack on wrist flexor muscles and the muscle endurance was improved probably due to enhanced blood flow to the muscles. The second theory was not checked in our study as we heated the muscles locally. Therefore we did not confront negative effects of general heating and its impact on core temperature.

Previous studies showed unaffected maximal isometric force by heating [13,16]. However, an improvement in force-velocity relationship of gripping muscles was reported [16]. Researchers claimed that by increasing muscles temperature from 22 to 38 centigrade degrees, no enhancement in maximal isometric force was seen. However, the contractile velocity increased significantly in this temperature range [17]. Therefore it is concluded that local increase in tissue

**Table 1:** The effect of temperature on wrist flexor muscles endurance

	Pre	Post heating	Post cooling
Wrist flexor muscles endurance (second)	83.26±5.62	86.66±7.65 *	80.80±5.42 *
Skin Temperature (°C)	37.35±0.23	38.70±0.69 *	35.48±1.07 *

\*: P Value<0.05

temperature did not affect maximal isometric force although it may have some impact on muscles endurance [13,16-17].

We also found that cooling the wrist flexor muscles reduce their endurance significantly. The possible explanation for this result may be that cooling muscles may decrease blood flow to the muscles due to induced vasoconstriction. It has been previously reported that immersion of hand in cold water reduced skin temperature, nerve conduction velocity and grip ability [18]. De Ruiter et al also showed maximal isometric force of adductor pollicis muscle, force velocity and muscle relaxation ability was reduced by cooling [1]. Negative effects of cold environment on human physical capability has been already shown. More recently increase in Electrophysiological activity, fatigue and risk of injury was reported as well [19,20]. The reason behind these effects may be explained by reflexive vasoconstriction and vasodilatation induced by cold. When the body is exposed to cold for a long time, a vasodilatation followed the primary vasoconstriction provoked by cooling the body. Ducharme explained that this vasodilatation happened in order to improve muscle function [21]. When hands are exposed to cold, people usually report discomfort, pain, stiffness, numbness and paresthesia. These feelings may affect on muscles function negatively. Furthermore, it seems that during submaximal contractions, there is a tendency toward increase in the numbers of active motor units so as to compensate the negative effects of cooling. Whereas, in maximal voluntary contractions (MVC), cooling leads to reduce the force production [22]. In the present study, participants performed a submaximal contraction with 20% to 30% of their MVCs. Therefore, it is probable that more motor units were activated to compensate the negative effects of cold on force production. As a result they meet the fatigue sooner than the normal situation.

There were some limitations of this study. The first limitation was regarding our laboratory facilities. We could not measure the muscle temperature after applying ice or hot packs due to lack of the special technology as well as. Future study is suggested to investigate the muscle temperature after applying ice or hot packs in order to know to what extent these packs can affect the muscle itself. Another limitation was that our participants were male only. Future study is recommended to evaluate effects of gender on temperature adaptability.

The findings of this study demonstrated that applying hot and ice pack to the palmar surface of the forearm lead to increase and decrease the wrist flexor endurance respectively. Therefore, it should be considered that environment temperature may affect the endurance capacity of wrist flexor muscles and consequently, their lifting capacity. It may take more attention in workplaces of extreme temperature.

## Conclusion

The results of the present study demonstrated that grip capability is related to the muscles temperature. Increase in muscles temperature caused muscles endurance enhancement. However, applying cold on the muscles

reduced their endurance.

**Conflict of Interest:** None declared.

## References

- De Ruiter CJ, Jones DA, Sargeant AJ, De Haan A. Temperature effect on the rates of isometric force development and relaxation in the fresh and fatigued human adductor pollicis muscle. *Experimental Physiology*, 1999,84:1137-1150.
- Ranatunga KW. Force and power generating mechanisms in active muscle as revealed from perturbation studies. *Journal of Physiology*, 2010,588:3657-3670.
- Saboisky J, Marino F E, Kay D, Cannon J. Exercise heat stress does not reduce central activation tonon-exercised human skeletal muscle. *Experimental Physiology*, 2003 88: 783–790.
- Nybo L, Nielsen B. Hyperthermia and central fatigue during prolonged exercises in humans. *Journal of Applied Physiology*, 2001, 91:1055-1060.
- Geurts CLM, Sleivert GG, Cheung SS. Local cold acclimation of the hand impairs thermal responses of the finger without improving hand neuromuscular function. *Acta Physiologica Scandinavica*, 2005,183: 117-124.
- Burke DG, MacNeil SA, Holt LE, MacKinnon NC, Rasmussen RL. The effect of hot or cold water immersion on isometric strength training. *Journal of Strength and Conditioning Research*. 2000,14: 21-25.
- Sanya AO, Bello AO. Effects of cold application on isometric strength and endurance of quadriceps femoris muscle. *African Journal of Medicine and Medical Sciences*, 1999,28:195-198.
- Verducci FM. Interval cryotherapy decreases fatigue during repeated weight lifting. *Journal of Athletic Training*, 2000,35: 422-426.
- Hopkins JT, Stencil R. Ankle cryotherapy facilitates soleus function. *Journal of Orthopaedic Physical Therapy*, 2003,32: 622-627.
- Drinkwater E. Effects of peripheral cooling on characteristics of local muscle. *Medicine and Sport Science*. 2008;53:74-88.
- Kimura IF, Gulick DT, Thompson GT. The effect of cryotherapy on plantar flexion peak torque and endurance. *Journal of Athletic Training*. 1997,32: 124-126.
- Ruiz DH, Myrer JW, Durrant E, Fellingham GW. Cryotherapy and sequential bouts following cryotherapy on concentric and eccentric strength in the quadriceps. *Journal of Athletic Training*, 1993,28:320-323.
- Nodehi Moghadami A, Dehghane N. The effects of local heating and cooling of arm on maximal isometric force generated by the elbow flexor musculature in male subjects. *Iranian Rehabilitation Journal*. 2012; 10 (15) :62-65.
- The effect of passive heating and head cooling on perception, cardiovascular function and cognitive performance in the heat.
- Shrout PE, Fleiss JL. Intraclass correlation: use in assessing rater reliability. *Psychological Bulletin*. 1979; 86:420-8.
- Davies C. T. M, Young K. Effect of temperature on the contractile properties and muscle power of triceps surae in humans. *Journal of Applied Physiology* 1983. 55, 191-195.
- Binhhorst R. A, Hoofd L, Vissers A. C. A. Temperature and force-velocity relationship of human muscles. *Journal of Applied Physiology* 1977. 42, 471-475.
- Brazaitis M, Skurvydas A, Vadopalas K, Daniuseviciute L, Senikiene Z. The effect of heating and cooling on time course of voluntary and electrically induced muscle force variation. *Medicina (Kaunas)*, 2011, 47: 39-45.
- Cheng CC1, Shih YC, Tsai YJ, Chi CF. The influence of cooling forearm/hand and gender on estimation of handgrip strength. *Ergonomics*. 2014; 57(10):1499-511.
- Oksa J, Ducharme MB, Rintamaki H. Combined effect of repetitive work and cold on muscle function and fatigue. *Journal of Applied Physiology*, 2002, 92 :354:361.
- Ducharme MB, Van Helder WP, Radomski MW. Cyclic intramuscular temperature fluctuations in the human forearm during cold water immersion. *European Journal of Applied Physiology*. 1991, 63:188-193.
- Chi CF, Shih Y, Chen W. Effect of cold immersion on grip force, EMG, and thermal discomfort. *International Journal of Industrial Ergonomics* 42 (2012) 113-121.