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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

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Effects of cooling on ankle muscle maximum performances, gait ground reaction forces and electromyography (EMG)

Amitava Halder^{1,2*}, Chuansi Gao², Michael Miller¹, Ingvar Holmér²

¹ Division of Physiotherapy, Department of Health Science, Faculty of Medicine, Lund University, Sweden

² Division of Ergonomics and Aerosol Technology, Department of Design Sciences, Faculty of Engineering, Lund University, Sweden

*corresponding author: Amitava.Halder@design.lth.se

Introduction

Temperature is considered as a significant determinant of skeletal muscle function and performance [1, 2]. There is evidence that, there is an optimal temperature range where the best performance of muscle occurs. [3]. Controversial evidence is found in the literature which has examined the effects of decreased muscle temperature on muscle contractile properties. There have been several reports that muscular contraction force and rate of force development were impaired at low muscle temperature [4,5].

Since 1868, a lot of studies have focused on the muscle function and performance influenced by temperature [6]. Some investigations have dealt with the role of local temperature on skeletal muscle performance, yet its effects on neuromuscular function and performance through gait still remain unexamined. The purpose of this study was to assess the effects of cooling on the muscle performance through maximum force, muscle electrical activities during low dynamic and static contraction and ground reaction force during gait. Since no studies have investigated the relationship between the ankle muscle strength, ground reaction force during gait and EMG before and after cooling. It was hypothesized that, cooling and fatigue on muscle characteristics, maximal force and required force during gait would be reduced also affect the electrical activities of specific muscles of the lower extremities such as tibialis anterior (TA) and gastrocnemius medialis (GM).

Methods

The experimental study was carried out through within subject design. All volunteer participants signed the informed consent form. Sixteen healthy university students participated in the study, 8 males and 8 females, mean \pm SD: age, 27.0 \pm 2.9 years; body mass, 66.3 \pm 9.8 kg; height, 169.5 \pm 7.8 cm. The study (project no. 100026) was approved by the regional ethical review board in Lund (EPN), and performed in according to declaration of Helsinki for research involving human subjects. Two experimental stations were designed for the experiment with one in a 'room temperature environment' where a walkway with a force plate was placed while the other experimental station was in a 'cold climate chamber' with a chair and water container. A physical examination bed was also placed inside the climatic chamber to allow the individual to be supine during the dynamometer measurement.

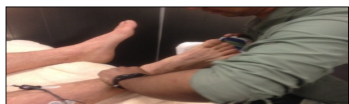


Figure 1. Hand held dynamometer was used to measure plantar flexion strength against foot resistant.

The subjects were instrumented by attaching EMG electrodes to the skin of muscle belly by shaving or abrading to minimize the electrical impedance, followed by the isometric resisted tests through using a hand held dynamometer while lying on the supine on the examination bed in cold

climate chamber and then walking over the ground reaction force plate while EMG data were obtained. Before immersion the subjects was fully prepared by wearing necessary clothes. The local cooling was induced by immersing both lower legs up to knee for 20 min in the cold water (10°C) in a climate chamber with air temperature being kept at 9.5°C. Electromyographic (Megawin' ME6000-T16 Mega Electronics, Kuopio, Finland) activities and strengths of the ankle dorsi and plantar flexors maximum isometric forces were measured in tibialis anterior and gastrocnemius medialis muscles by using surface electrodes and 'Lafayette Hand Dynamometer' (model: LA-01163 IN, US). Ground reaction forces during gait were measured with force plate (Kistler 9281B Switzerland) while the subjects were walking on the walkway.

Results and Discussion

There was a significantly reduced isometric maximum force in TA muscle ($p<.001$) after cooling. The mean EMG amplitude of GM muscle was significantly increased after cooling ($p<.003$). There were no significant changes in ground reaction forces and required coefficient of friction (RCOF) in gait trials after cooling. RCOF is the ratio of Fy over Fz and is used to assess slip risk. If available coefficient of friction is smaller than RCOF, a slip will occur. The main findings showed that the cooling decreased maximum force of the TA but not the GM muscle. The study also showed that cooling increased the EMG amplitude significantly of the GM but not the TA during the maximum voluntary contractions and gait trials. These results partly support initial hypothesis that maximum lower leg muscle force decreases through ankle maximal voluntary contractions. (see Table 1 & 2).

Table 1. The means and standard deviations of the three MVC trials as well as the mean EMG amplitude during the three MVC trials, and median EMG (normalized) during three gait trials are given for the TA and GM muscles before and immediately after cooling (n=16).

		MVC							
		Dorsi Flexion (TA)			Planter Flexion (GM)				
		Pre Cooling	Post Cooling	Sig. 'P' value	Pre Cooling	Post Cooling	Sig. 'P' value		
Parameters	Mean ± SD				Mean ± SD				
MVC Mean (Kg)	23.8±2.7	21.3±2.7		<.001	30.6±4.5	29.7±3.0	.221		
		EMG (MVC)							
		Tibialis Anterior			Gastrocnemius Medialis				
		Mean ± SD		Sig. P value	Mean ± SD		Sig. P value		
				't' Test			't' Test		
				WSR test*			WSR test*		
EMG (MVC) Mean (µV)	446.4±218.2	443.4±250.7		.939	284.8±128.3	705.5±487.7	.003		
		EMG during Gait trials (normalized values in %)							
Gait trial EMG	11.3±5.3	13.1±7.3		.158	.077	13.6±10.3	19.8±11.9	<.001	.004

*Non-parametric 'Wilcoxon Signed-Rank' Test for EMG data.

Table 2. Vertical and longitudinal Ground Reaction forces (normalized by body weight) during heel strike and toe-off in relation to dorsi-flexion and plantar flexion respectively before and after cooling (n=16).

Ground Reaction Forces (GRF)						
	Heel Strike (HS) Phase			Toe-Off (TO) Phase		
	Pre Cooling	Post Cooling	Sig. 'P' value	Pre Cooling	Post Cooling	Sig. 'P' value
Forces (normalized)	Mean ±SD			Mean ±SD		
Peak Vertical (Fz)	1.14±.11	1.17±.10	.140	1.15±.08	1.14±.06	.186
Peak Longitudinal (Fy)	-.21±.05	-.21±.06	.903	.24±.03	.23±.03	.129
Required Coefficient of Friction (RCOF)*	.26±.04	.25±.05	.851			

*RCOF during heel strike phase was included in the analysis.

A significant decrease in MVC strength was observed from pre to post cooling for dorsi-flexion (DF) only, whereas, EMG amplitude for plantar flexion (PF) in GM muscle significantly increased. This might be induced by muscular fatigability as it was proved that fatigued muscular EMG during isometric contraction increased the amplitude [7]. One possible reason for the discrepancy of GM MVC not being affected might be that due to, GM being a much larger muscle than the TA, the drop in temperature of this large muscle was less affected by the cooling method of this study. Furthermore, it has been reported that EMG amplitude of the fatigue and cooled working muscles increased amplitude on isometric and sub-maximal exercise is due to recruiting more fibres to produce the same force [7,8].

The analysis of ground reaction force showed no significant alterations on peak vertical and longitudinal ground reaction forces. However, a small decrease can be seen in vertical force during the heel strike and toe-off phases and also some decrease in the longitudinal anterior-posterior force during the heel strike phase. Eils et al. [9] and Stål et al. [10] showed that an anaesthetic effect on feet by following ice water immersion and reported that gait changed on a force plate, such that the timing of first (HS) and second peak (TO) was modified by delaying and braking and acceleration forces were also reduced. As this study also used cold water, the cutaneous sensation might have reduced [11].

The results of this study concerning the cooling effects were consistent with the hypothesis in matter of muscular performance except ground reaction forces. These non significant changes of ground reaction forces after cooling might be explained by the task of walking on a level and dry vinyl surface not being demanding enough. Gait speed could be an another determination, subjects were asked to walk only a few steps on a 7.5 m walkway, so the speed required to complete a trial was low might not affected the ground reaction forces. Sport and work performance may decline due to local cooling in cold environments where subject may not produce their maximum force. Ground reaction forces may be affected by the cooling during high velocity human movement. It would be interesting to examine sports surfaces where athletes produce force for momentum for example, jumping surfaces to evaluate the performance. It is still not clear how about cooling influence muscle fatigue; further studies are needed to compare fatigue muscle characteristics of repetitive movements with muscle characteristics after cooling.

Conclusions

In conclusion, the present study showed that neuromuscular performances were partly altered after cooling. Maximum strength loss occurred in dorsi-flexion (TA). Fatigued, over-exerted power loss observed in plantar flexion (GM) though cooling did not make a significant contribution to normal gait ground reaction forces on a dry and level surface. These may indicate that 20 min cooling in cold water at 10°C can influence our maximum muscle performance, but the cooling may not be severe enough to impact our daily sub maximal activities.

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