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Original Article

Effect of quadriceps and hamstrings muscle cooling on standing balance in healthy young men

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Abstract

Objective: The present study compared the effect of quadriceps and hamstring muscle cooling on standing balance in healthy young men. **Methods:** Thirty healthy young men (18-30 years) participated in the study. The participants were randomly assigned to three groups (n=10 each): quadriceps cooling (QC), hamstring cooling (HC), or control group (no cooling). Participants in the QC and HC groups received 20 minutes of cooling using a cold pack (gel pack), placed on the anterior thigh (from the apex of the patella to the mid-thigh) and the posterior thigh (from the base of the popliteal fossa to the mid-thigh), respectively. Balance score including unilateral stance was measured at baseline and immediately after the application of the cold pack. **Results:** No significant difference in the balance score was noted in any group after the application of the cold pack ($p>0.05$). Similarly, no significant differences in post-test balance score were noted among the three groups ($p>0.05$). **Conclusions:** Cooling of the quadriceps and hamstring muscles has no immediate effect on standing balance in healthy young men. However, longitudinal studies are warranted to investigate the long-term effects of cooling these muscles on standing balance.

Keywords: Cooling Effect, Balance, Ice, Men

Introduction

Cryotherapy in the form of ice packs, gel packs, and ice immersion is commonest treatment regime for minor acute musculoskeletal injuries[1,2]. While ice is known to effectively decrease pain and tactile sensations, its effect on balance has earned comparatively little attention. In addition to various benefits of cryotherapy treatment, reduced performance scores were reported immediately after cryotherapy[3]. Reduced muscle strength, vertical jump, speed, and agility variables were reported following cryotherapy in previous studies[4-7]. Another study reported increased postural sway following cryotherapy in individuals with a history of lateral ankle sprains[8].

Proper balance is controlled by the combined functions of the vestibular, somatic, and visual senses[9]. Any alteration to these systems may affect balance, and one such disturbance may be reduced blood flow to a body part due to cold exposure[10]. The redistribution of blood flow due to cold exposure may affect the neuromuscular and somatosensory systems that are vital for the execution of tasks for example, balance and strength[11,12].

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Abbreviations
ANOVA = analysis of variance
BMI = body mass index
COG = center of gravity
EC = eyes closed
EO = eyes open
HC = hamstring cooling
QC = quadriceps cooling; US = unilateral stance

In addition, for every 1°C reduction in skin temperature and muscle temperature, the nerve conduction velocity reduces by 1.5-2 m/sec and muscle spindle firing rates drop by 1-3 pulses per second[13,14]. Furthermore, the exposure to rapid decreases in temperature causes exteroceptive mechanoreceptors to display temperature-sensitive firing patterns by demonstrating thermoreceptor-like functions[15].

Previous studies reported that the skin is an organ with the ability to influence proprioception[16-18]. A reduction in skin temperature can alter sensory afferent information via cutaneous receptors[17]. Ice was applied to decrease skin temperature during proprioceptive evaluations[19,20]. Many studies reported reduced sensory afferent information following ice application[21-23]. Haupenthal et al.[24] recently reported reduced proprioceptive function of the ankle-dorsiflexor muscles following skin cooling.

Previous studies reported decreased balance control following application of ice to the lower limb, specifically to the ankle and foot[6,8,25]. Perry et al.[26] proclaimed that the capability to maintain an upright posture with external perturbations was significantly reduced after the ice-water immersion of the plantar surface of the feet. In addition, Piedrahita et al.[27] reported a reduction of 9-11% in end point excursion during a limit of stability test with cold water immersion to the foot and ankle at 15°C for 1 hour. However, Hopkins et al.[28] reported no impairment in reaction time or immediate muscle activation during inversion perturbation following ankle joint cooling when compared to the control. In addition, Tremblay et al.[29] reported no changes in the proprioceptive function in the quadriceps muscle group following prolonged cooling of the thigh. In contrast, Oksa et al.[30] reported reduced muscle spindle activity following muscle tissue cooling. Previous studies suggested that muscle cooling invokes a different motor response than to joint cooling[31,32]. However, Oliveira et al.[33] reported no significant effect on cooling the knee joint versus cooling only the quadriceps muscle. A previous systematic review demonstrated that some studies indicated that the application of cryotherapy causes an impaired proprioceptive function, while others indicated no changes in proprioceptive function[19]. Therefore, additional studies are warranted to obtain conclusive evidence. In addition, the role of the quadriceps and hamstring muscles in maintaining standing balance is well established[34,35], but the effect of their cooling on standing balance has not been reported previously. Thus, this study aimed to compare the effect of quadriceps and hamstring muscle cooling on standing balance in healthy individuals.

Materials and methods

Participants

Healthy young men aged 18-30 years recruited from the College of Applied Medical Sciences (CAMS), King Saud University, Riyadh, participated in this study. Subjects were excluded if they had a history of a hip or knee injury, sensory deficits in the lower extremity, a history of lower-extremity surgery, or a history of a quadriceps or hamstring muscle injury. The protocol was submitted to and approved by the CAMS Research Ethics Committee of King Saud University (CAMS 21/3536). Participants were asked to sign a written informed consent form approved by the institution ethics committee of King Saud University. A total of 30 participants were randomly assigned to the quadriceps cooling (QC: n=10), hamstrings cooling (HC: n=10) or control (no cooling: n=10) group by a lottery method.

Procedure

Demographic variables including age, height, and weight were measured. A baseline assessment of mean center of gravity (COG) sway velocity (degrees/sec) for the unilateral Stance (US) was performed. After the baseline assessment, the participants in the QC group were asked to lie down in a supine position and a cold pack (gel pack, temperature -6°C to -12°C) was placed on the anterior thigh (from the apex of the patella to the mid-thigh) of both limbs for 20 minutes. The participants in the HC group were asked to lie down in a prone position and a cold pack (gel pack, temperature -6°C to -12°C) was placed on the posterior thigh (from the base of the popliteal fossa to the mid-thigh) of both limbs for 20 minutes. One thin dry towel was kept between the cold pack and the skin to prevent skin damage. Before and after the application of ice application the skin sensibility was briefly assessed by testing the participant's to a pinprick. The application of a cold pack has been shown to reduce subcutaneous temperature by 17°C and intramuscular temperature by 7°C in a 20-minute intervention[36]. Participants in both the test groups reported reduced sensation and diminished response to a pinprick in the cooled area. Following the manufacturer's recommendations, the gel pack was frozen for at least 4 hours before application. A Hydrocollator cold pack chilling unit (ColPac®, Model C-6; Chattanooga, TN, USA) was used to freeze the gel pack. The participants in the control group rested without any intervention.

Outcome assessment

In the balance assessment, mean COG sway velocity (degrees/sec) for the US was tested on a force plate (NeuroCom Balance Master®; Natus Medical Incorporated, CA, USA)[37]. The participants stood in the marked position on the force plate, with their hands positioned on the iliac crests[38]. The participants were asked to lift the right foot to a standard height of 10 cm. This 10-second test was performed three times in two test conditions, including eyes open (EO) and eyes closed (EC). The mean COG sway velocity (degrees/sec) from three trials of the US was used in the analysis. The participants were requested to perform the same test for the left leg. The US was used to determine each participant's ability to maintain postural stability during unilateral standing in the EO and EC conditions. The US improves the observational testing of the US by giving an objective score of sway velocity (in degrees/sec)[39,40]. All tests were performed

Table 1. Participant's characteristics.

	Quadriceps cooling	Hamstring cooling	Control (no cooling)	ANOVA	
				F	*p
Age, years	27.8 (2.3)	27.6 (2.1)	27.2 (0.9)	0.309	0.740
Weight, kg	76.5 (8.6)	79.7 (7.8)	77.3 (13.6)	0.199	0.847
Height, m	1.7 (0.06)	1.7 (0.04)	1.7 (0.01)	0.055	0.970
BMI, kg/m^2	27.9 (2.7)	27.6 (3.7)	26.7 (6.2)	1.417	0.137

*ANOVA, analysis of variance; BMI, body mass index. Data are presented as mean±standard deviation; *P<0.05 (significant).*

Table 2. Descriptive statistics of clinical data of quadriceps cooling, hamstring cooling, and no cooling (control) groups.

		Pretest (mean COG sway velocity, degrees/sec)	Posttest (mean COG sway velocity, degrees/sec)	ICC	Effect Size (Cohen's d)
Quadriceps cooling (left US)	EO	1.2 (0.43)	1.18 (0.49)	0.56	0.04
	EC	3.06 (1.28)	2.85 (0.87)	0.82	0.19
Quadriceps cooling (right US)	EO	0.96 (0.14)	1.03 (0.18)	0.84	0.44
	EC	3.26 (1.37)	2.66 (0.86)	0.46	0.49
Hamstring cooling (left US)	EO	1.03 (0.33)	1.05 (0.20)	0.42	0.07
	EC	2.93 (1.12)	3.37 (1.07)	0.37	0.40
Hamstring cooling (right US)	EO	1.03 (0.23)	1.09 (0.19)	0.32	0.28
	EC	3.17 (1.19)	2.89 (1.49)	0.61	0.21
No cooling (control) (left US)	EO	0.93 (0.18)	0.93 (0.14)	0.47	0.31
	EC	3.24 (1.07)	2.87 (0.97)	0.70	0.36
No cooling (control) (right US)	EO	1.01 (0.22)	0.98 (0.10)	0.60	0.11
	EC	3.32 (0.84)	2.47 (0.75)	0.19	0.42

COG, center of gravity; EO, eyes open; EC, eyes closed; US, unilateral stance; ICC, Intra class coefficient.
Data are presented as mean±standard deviation.

at baseline and immediately (usually within 2-3 minutes) after the cooling protocol was performed.

Statistical analysis

The statistical analysis was done using SPSS software version 22 (SPSS, Chicago, IL, USA). All results are reported as mean ± standard deviation. Two-way repeated-measures analysis of variance (ANOVA; intra-subject factors; time [pretest, post-test] and tested conditions [EO and EC]) was used to compare intragroup differences in balance score. In addition, two-way mixed-design ANOVA (inter-subject factor, groups [QC, HC, and control]; intra-subjects factor, tested conditions [EO and EC]) was used to compare intergroup differences in balance score. If interactions were detected, a post hoc analysis with Bonferroni adjustment was used. Test-retest reproducibility of the outcome scores were analyzed using the $ICC_{2,1}$. In addition, effect size (ES) of intervention in each group was estimated. The magnitude of ES was considered as follow: ES>0.8 is large, 0.5 to 0.8 is moderate, and 0.2 to 0.5 is small[41]. The level of significance was set at $p<0.05$.

Results

The intergroup differences in the patients' demographic variables were insignificant (Table 1). Table 2 presents the test-retest reproducibility, ES, and descriptive statistics of the clinical data of the QC, HC, and control groups. An intragroup comparison of the balance scores of the QC, HC, and control groups using two-way repeated-measure ANOVA showed insignificant effects in all tested conditions (Table 3). A comparison of the balance scores of the QC, HC, and control groups using two-way mixed-design ANOVA showed insignificant differences in all tested conditions (Table 4).

Discussion

The present study aimed to compare the effect of quadriceps and hamstring muscle cooling on standing balance in healthy young men. In the present study, the participants were assessed for sway velocity (degrees/sec)

Table 3. Intragroup comparison of balance scores using two-way repeated-measures analysis of variance.

Tests of Intra-subjects Contrast						
Measure: Mean COG sway velocity, degrees/sec (left US)						
Source	Time	Type III sum of squares	df	Mean square	F	*P
Time (pre-test, post-test)	Linear	0.016	1	0.016	0.049	0.83
Time × group (QC, HC, CC)	Linear	0.987	2	0.494	1.483	0.24
Time × test condition (EO, EC)	Linear	0.016	1	0.016	0.049	0.83
Time × group × test condition	Linear	0.857	2	0.429	1.288	0.28
Measure: Mean COG sway velocity, degrees/sec (right US)						
Time (pre-test, post-test)	Linear	2.187	1	2.187	5.159	0.027
Time × group (QC, HC, CC)	Linear	0.528	2	0.264	0.623	0.54
Time × test condition (EO, EC)	Linear	2.821	1	2.821	6.656	0.013
Time × group × test condition	Linear	0.312	2	0.156	0.368	0.69

*Left US, unilateral stance on the left foot; QC, quadriceps cooling; HC, hamstring cooling; CC, control (no cooling); EO, eyes open; EC, eyes closed; right US, unilateral stance on the right foot; *P<0.05 (significant).*

Table 4. Intergroup comparison of balance scores using two-way mixed-design analysis of variance.

Tests of Inter-subjects Effects					
Dependent Variable: Mean COG sway velocity, degrees/sec (left US)					
Source	Type III sum of squares	df	Mean square	F	*P
Corrected model	60.657[a]	5	12.131	23.059	0.000
Intercept	250.104	1	250.104	475.400	0.000
Group (QC vs HC vs CC)	0.982	2	0.491	0.934	0.39
Test condition (EO Vs EC)	58.608	1	58.608	111.403	0.000
Group × test condition	1.066	2	0.533	1.013	0.37
Dependent Variable: Mean COG sway velocity, degrees/sec (right US)					
Corrected model	41.289[a]	5	8.258	13.883	0.000
Intercept	206.091	1	206.091	346.479	0.000
Group (QC vs HC vs CC)	0.704	2	0.352	0.592	0.56
Test condition (EO Vs EC)	40.344	1	40.344	67.826	0.000
Group × test condition	0.241	2	0.120	0.203	0.82

*a. R^2 = .681 (adjusted R^2= 0.651). COG, center of gravity; left US, unilateral stance on the left foot; QC, quadriceps cooling; HC, hamstring cooling; CC, control (no cooling); EO, eyes open; EC, eyes closed; right US, unilateral stance on the right foot, *P<0.05 (significant).*

in the US in two tested conditions. The results of the present study revealed insignificant differences in pre- and post-test balance scores following quadriceps and hamstring muscle cooling (p>0.05). Piedrahita et al.[27] reported decreased ability to maintain dynamic balance following cooling of the lower leg (popliteal area to the feet) in a healthy women. Similarly, Douglas et al.[41] reported reduced mediolateral dynamic balance following cryotherapy of the ankle; however, they reported no difference between ice application and control in static and overall balance scores. Nevertheless, a direct comparison of these studies with the present study is not possible since Piedrahita et al.[27] and Douglas et al.[42] used different methodologies. However, both the studies provided lower-leg cooling using ice water immersion. The temperature of the cold water was 4.4°C and 15°C in the studies by Douglas et al.[41] and Piedrahita et al.[27], respectively. Douglas et al.[42] measured anteroposterior and mediolateral stability as balance indices, while Piedrahita et al.[27] measured the limit of stability as a balance index. In addition, Piedrahita et al.[27] included only female participants. Furthermore, in previous studies, ice was applied to the lower leg[27] or ankle joint[42]. However, in the present study, the cold pack was applied to the quadriceps or hamstring muscles. Therefore, it is assumed that the effect of cooling on the lower leg or ankle joint would increase as the cooling energy dissipates in the smaller area compared to the larger thigh area. In addition, a previous study reported that the distribution of blood flow corresponds to the muscle mass; therefore, the larger masses of the thigh muscles compared to the smaller masses of the lower leg muscles resulted in greater blood flow[43]. Hence, greater blood flow could minimize the cooling effects in the thigh area (quadriceps or hamstrings) than in the lower leg or ankle joint.

The information consolidated from different body systems, including the vestibular, vision, and proprioception systems, is desirable for proper balance[44]. A previous study reported a significant effect of temperature on the neuromuscular system, and the cooling of the nerves may slow down the neural transmission of both afferent and efferent information, thereby impairing postural control[45]. Other studies reported that local leg cooling can affect the peripheral mechanisms that control balance[46,47]. Stal et al.[46] reported that cooling can affect the ankle mechanoreceptors, resulting in increased balance postural sway. Oksa et al.[47] reported that the decreased activity of the muscle spindles can affect neuromuscular control, resulting in the suppression of tendon reflex amplitudes and thereby affecting neuromuscular control. In addition, a previous study reported the reduction of nerve conduction velocity following cryotherapy, consequently affecting proprioception[2]. However, in the present study, changes in skin and muscle temperature after the application of the clod pack were not measured. In addition, nerve conduction velocity and spindle activity after the application of the cold pack were not assessed. Therefore, in the present study, what mechanism altered the balance after the application of the cold pack to the quadriceps or hamstring muscles is unclear.

A previous systematic review indicated that the ice therapy had no negative effects on joint position sense across various joints[19]. Although some studies reported reduced proprioception after cooling, others reported equivocal results[48-53]. Hopkins et al.[28] reported no changes in reaction time or immediate muscle activation after ankle joint cooling. In addition, Tremblay et al.[29] reported no impairment in the proprioceptive acuity of the quadriceps muscle group after prolonged thigh cooling. However, Oksa et al.[30] reported impaired muscle spindle activity after muscle tissue cooling. Previous studies indicated that the muscle and joint cooling have different motor responses[31,32]. In contrast, Oliveira et al.[33] found no significant effect of knee joint cooling compared to only quadriceps muscle cooling. In addition, Saam et al.[54] reported that the application of cryotherapy to the ankle joint for 10 minutes did not alter the static balance in the US.

The present study had some potential limitations. First, healthy subjects were used to provide an indication of how cooling of the quadriceps or hamstring muscles affects standing balance. However, subjects with an acute or chronic lower-extremity injury might respond differently to cooling. Second, the changes in temperature of the skin or muscles following the application of the cold pack were not evaluated. Furthermore, testing of the conduction velocity would provide a better understanding of the cooling effect. Third, due to lack of a priori sample size estimation, the present study may have been underpowered to detect a significant effect of cooling on balance. A large randomized, controlled study is warranted to verify the effect of cooling the quadriceps and hamstring muscles on standing balance in healthy young men. Fourth, local adipose tissue thickness was not measured in this study; however, in previous studies, a significant inverse relationship between the amount of subcutaneous fat and the intramuscular temperature change was reported[55,56]. Fifth, time required for the cooling effect to wear off was not tested.

Cooling of the quadriceps and hamstring muscles has no immediate effect on standing balance in healthy young men. However, longitudinal studies are warranted to investigate the long-term effects of cooling of these muscles on standing balance.

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Ethics approval and consent to participate

The protocol was submitted to and approved by the CAMS Research Ethics Committee of King Saud University (CAMS 21/3536). The participants were asked to sign a written informed consent form approved by the institution ethics committee of King Saud University.

Authors' contributions

SA: corresponding author, participated in the study design, participated in the data collection, drafted the manuscript, and finalized the manuscript. AA: participated in the study design, helped with the ethics application and revised the manuscript critically. HZ: participated in the study design, developed the protocol, and revised the manuscript critically. EA: participated in the study design and revised the manuscript critically. All authors read and approved the final manuscript.

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