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Original Article

Effects of cooling on hand grip strength among healthy young adults

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Abstract:
Background: The ability of cooling period to adjust muscle strength between gender and BMI (Body Mass Index) classification is not well understood, and the use of local cooling as a muscle strength technique is not well acknowledged. ***Purpose:*** This study aimed to investigate the effects of local cooling for 30s to 15 min with an ice pack technique on hand grip strength in healthy young adults depending on their gender and BMI classification. ***Methods*****:** Total participants in this study were 62 active young adults (aged 20.08 ±0.5 years old, BMI of 20.30 ±1.9 kg/m^2) to evaluate the effect of an ice pack (10–15°C) on their dominant wrist flexor muscles (1/3 proximal part). Grip strength (kg) was measured with a hand-held dynamometer before cooling as a baseline, at 30s and 15 min after cooling. The variations in grip strength depending on time were evaluated using a one-way repeated measures ANOVA. ***Results*****:** Grip strength was determined to be slightly lower in females after 30s and 15 min of cooling differentiated to the baseline ($p < 0.001$); this was not found in males. After cooling, BMI classification revealed association to changes in grip strength; specifically, a significant lowering in grip strength was monitored in the normal-weight category ($p < 0.001$). ***Limitations:*** In this study, subject's skin temperature was not controlled, and the menstrual cycle in female participants was not monitored even though it could have affected the results. ***Conclusion*****:** Grip strength was significantly correlated with cooling in the female and normal-weight groups. This result suggests that the effects of ice pack cooling on grip strength are dependent on the characteristics of the participants.
Key Words: **cryokinetics, ice pack, gender, body composition, exposure duration, muscle strength**

Introduction

Muscle strength, muscle capacity and muscle endurance are three principles that define human muscle function. Muscle strength refers to the ability of a person to apply maximal muscular energy in a specific movement pattern at a specific speed against any form of resistance (Hasan et al., 2016). Only few methods for measuring muscle strength have been scientifically tested. In many activities, grip strength measurement is recommended and proven reliable as a primary approach to measure muscular function. It is a simple technique with a high level of accuracy (Beaudart et al., 2019). Furthermore, grip strength in middle age might predict physical incapability in future life, and it can be used as a screening tool to assess upper body and overall strength (Litchfield, 2013). Typically, it is measured manually using dynamometry, which tests isometric muscle strength in kilograms by squeezing. While a prior study revealed that no difference on dominant and non-dominant in both absolute and relative grip strength (De A. Oliveira et al, 2018).

Many daily physical activities require repeated forearm contractions, and forearm strength is considered to be a performance limiting factor (Balas et al., 2020). Previous studies revealed a clear relationship between muscle strength and anthropometric factors including age, gender, angle of pull, muscle cell length and size, number of motor units recruited, intensity and form of contraction, and body composition. Body mass index (BMI) is easy and acceptable screening method for weight category and is closely associated with health status (Hasan et al., 2016; Tsakalou et al., 2015). Previous studies inconsistently showed that muscle function did not indicate remarkably different between lean and obese individuals depending on age, height, physical activity and appendicular skeletal muscle mass. Since there were only few data existing on the impact of body mass index classifications and gender differences on grip strength in healthy young adults (Das and Dutta, 2015). However, compared to lean women, obese women exhibited reduced muscle strength in both the upper and lower limbs, which could be explained by their lower level of activity (Dhananjaya et al., 2017). Interestingly, lower muscle strength has been linked due to decreased levels of physical performance; sarcopenic obese individuals (a combination of insufficient muscular strength and high adiposity) is markedly harmful to physical capability. A higher BMI value is associated with the lower level of performance, which results in the lower level of muscle strength (Hardy et al., 2013).

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Previous study examined how the temperature influenced the level of development of isometric power in the lower arm after 20 min immersed in the water at 37, 31, 25, and 22°C. It was determined that isometric power was dropped at temperature under 25°C (Halder et al., 2014). However, a physiological response is related with the body surface exposed and the time of application (Rodríguez et al., 2020). Importantly, the ability of cooling to change muscle strength between different gender and BMI classification remains uncertain. The use of local cooling as a strategy to improve muscle strength is also not well-documented. Castle et al. observed three different ways of cooling and determined that ice packs were the most effective technique in lowering muscle temperature, possibly through producing thermal gradients for conductive cooling. All known techniques can lower skin temperature; however, ice pack is one of the cooling strategies that can lower muscle temperature (Castle et al., 2006). In a study of Gianoni et al. (2020) concluded that 30 seconds of cooling time between sets of resistance exercise did not result in an increase in the number of repetitions. As a result, it was recognized as the duration of cold exposure, protocol, and cooling technique could all have a different effects on an individual's performance (Kwon et al., 2013). Application of cold is a muscle cooling technique that is used to transfer heat energy from the skin and lower its temperature. Both forms of tissue are indirectly involved when the proposed structure is cooled (Rabelo et al., 2016). Muscle cooling can increase efficiency when physical tasks are repeatedly practiced for prolonged periods on the same day (Balas et al., 2020).

A previous study analysed the maximum grip strength of young healthy male and female students after forearm cooling (Rabelo et al., 2016). The therapeutic advantages of cold treatment have been excessively studied; however, the above mentioned study focused only on the arguable relationship between local cooling and muscle grip strength. The application of 15-min cold water immersion at 10°C effectively lowered grip strength. However, the study had a limitation because it focused on isometric grip strength by monitoring the surface or skin temperature; thus, the results based on anthropometric characteristic differences are still limited (Rabelo et al. 2016). In addition, significant variability was obtained possibly owing to imbalances of forearm muscle strength, anthropometric characteristics and body composition between genders after cooling application (Balas et al., 2020). Therefore, this current study purposed to evaluate the influences of local cooling application for different durations on forearm muscle strength of healthy young adults depending on gender and BMI classification.

Materials and Methods

Participants

This study was carried out on 62 young adults (18–21 years old) of both genders (20 males and 42 females). Males had an average age of 19.95 ± 0.4 years, and 20.14 ± 0.6 years for females (Table 1). They were healthy individuals (no reported skin, musculoskeletal, or neural disorders); enable of conducting maximum grip strength maneuvers. The participants with allergies or high sensitivity to cold exposure (such as Cold allergy, skin allergy, broken skin, or Raynaud's disease) were excluded (Rabelo et al., 2016; Muanjai and Namsawang, 2015). All of them participated voluntary in the study and they were able to drop out any time they wanted to.

Measurement Protocols

Anthropometric measurement

A portable digital scale (SECA 750; California, USA) was used to determine body weight. The participants were asked to wear light cloth, stand on the scale of equality, inhale and hold their breath. Body height measurements were performed with a standard stadiometer. The participants stood straight on a horizontal plate, barefoot, with their heels, buttocks, back, and occiput touching a vertical bar. The measurements were taken with the participant looking forward and inhaling.

BMI was calculated in kg/m^2 based on weight and height measurements. According to World Health Organization criteria, participants were classified as underweight: 18.5 kg/m^2, normal weight: 18.5–24.9 kg/m^2, overweight: 25.0–29.9 kg/m^2, or obese: 30.0 kg/m^2 (Weir and Jan, 2020).

Grip strength measurement

Grip strength measurement was performed using a digital hand-held dynamometer (TKK 5401; Takei Scientific Instruments Co., Ltd., Tokyo, Japan) under supervision by a well-trained physical therapist; the measurement was performed for a few seconds in a standing position. The measurement was modified so that the participants could comfortably hold the handle with palmar eminences and intermediate phalanges of dominant side. The participant was requested to compress the dynamometer with maximum grip force (Amaral et al., 2012).

Study Protocol

This pilot study was investigated at the Physical Therapy Laboratory, Faculty of Associated Medical Sciences, Khon Kaen University, Thailand. On the day of study, the participants were introduced to the objectives and study procedures through the reading and verbally explained. Then, it was performed anthropometric measurement all of participants and we performed a familiarization of grip strength measurement. Before the application of cooling, all participants used a hand-held dynamometer to measure their grip strength (kg) in standing position. Then, an ice pack (10–15°C) was placed with a plastic wrap around their dominant wrist flexor muscles (1/3 proximal part) in sitting position while holding their hand for 15 min in comfortable position. Their grip strength was measured 3 times during the experiment: before (T0), after 30s

(T1) and after 15 min (T2) of cooling. The highest score was used in the analysis. All procedures were performed at room temperature (25°C) as indicated from a previous study (Muanjai and Namsawang, 2015).

Statistical Analysis

Normal distributions were examined using the Shapiro–Wilk test. Levene's test was applied to assess the homogeneity of variances. The differences in measured variables between genders were analysed using an Independent sample t-test. One-way analysis of variance (ANOVA) was applied to test differences in baseline characteristics depending on BMI classification (i.e., underweight, normal weight, and overweight groups). One-way repeated measures ANOVA was used to analyse variances in grip strength depending on time periods (T0, T1 and T2). Bonferroni correction was used for multiple comparisons.

All statistical analyses were presented using SPSS Statistics 26 for Windows (IBM Corporation, Armonk, NY, USA). The level of significance was set at $p < 0.05$.

Results

The sample used in this study consisted of 62 healthy young adults (20 males and 42 females). Their mean age was 20.08 years (± 0.5 years), weight: 54.98 kg (± 8.8 kg), height: 164.13 cm (± 6.7 cm) and BMI value: 20.30 kg/m^2 (± 1.9 kg/m^2). Males had a slightly higher BMI than their female counterparts ($p < 0.05$). Table 1 shows that there was no valuable difference between gender and between BMI classification on their age ($p > 0.05$), while the height value was remarkably different ($p < 0.05$).

Table 1.**Baseline characteristics all of the participants (±SD)**

Characteristics of the participants	**Age** (years)	**Weight** (kg)	**Height** (cm)	**BMI** (kg/m^2)
Gender				
Males (n = 20)	19.95 ± 0.4	61.75 ± 10.6	170.35 ±4.8	21.15 ± 2.4
Females (n = 42)	20.14 ± 0.6	51.76 ± 4.5	161.16 ± 5.3	19.90 ± 1.4
p-value	0.14	0.001**	0.001**	0.04*
BMI classification				
Underweight (n = 6)	20.16 ± 0.4	48.66 ± 1.9	164.83 ± 3.6	17.90 ± 1.9
Normal weight (n = 51)	20.07 ± 0.5	53.49 ± 4.6	163.11 ± 5.9	20.05 ± 4.6
Overweight (n = 5)	20.00 ± 0.1	77.8 ± 9.0	173.60 ± 10.4	77.8 ± 9.0
p-value	0.11	0.06	0.04*	0.03*
Total (n = 62)	20.08 ± 0.5	54.98 ± 8.8	164.13 ± 6.7	20.30 ± 1.9

Note: Independent sample t-test was performed to analyse variances between genders; one-way ANOVA was applied to analyse variances between BMI classification; *p < 0.05, **p < 0.01.

Table 2.**Effects of cooling on absolute grip strength related to gender and BMI classification**

Characteristics of the participants	**Grip strength at T0** (Before the experiment) (kg)	**Grip strength at T1** (at 30s) (kg)	**Grip strength at T2** (at 15min) (kg)	**F**	**p-value**	**Partial Eta Squared** (Effect size)
Gender						
Male (n = 20)	39.60 ± 10.6	40.29 ± 10.8	38.78 ± 9.4	0.85	0.43	0.04
Female (n = 42)	25.68 ± 5.6[b]	25.50 ± 5.2[c]	22.93 ± 6.2	13.61	0.001**	0.23
BMI classification						
Underweight (n = 6)	25.00 ± 4.7	25.61 ± 3.0	23.43 ± 6.5	0.68	0.53	0.12
Normal weight (n = 51)	29.16 ± 8.2[b]	29.35 ± 8.9[c]	27.22 ± 9.6	9.42	0.001**	0.16
Overweight (n = 5)	46.64 ± 5.6	44.78 ± 6.2	41.98 ± 2.8	0.94	0.43	0.19
Total (n = 62)	30.17 ± 9.9[b]	30.23 ± 10[c]	28.05 ± 10.4	10.50	0.001**	0.15

Note: One-way repeated measures ANOVA was performed to analyse variances in grip strength between T1, T2 and T3; Bonferroni post-hoc test was applied for multiple comparisons; [a]significant difference between T0 and T1 (p < 0.01), [b]significant difference between T0 and T2 (p < 0.01), [c]significant difference between T1 and T2 (p < 0.01); *p < 0.05, **p < 0.01

The results in Tables 2 and 3 were analysed using one-way repeated measures ANOVA between three different time periods and using the Bonferroni post-hoc test. In female participants, 15 min of cooling application showed a significant (12%) reduction in grip strength (25.68 ± 5.6 kg vs. 22.93 ± 6.2 kg, respectively) and relative grip strength (0.49 ±0.1 kg vs. 0.44 ± 0.1 kg, respectively) when comparing between before cooling (T0) and after 30s of cooling (T1) trials ($p < 0.01$). Moreover, g*rip strength and relative grip strength significantly reduction* ($p < 0.01$) between the time of 30s (T1) and 15 min (T2) cooling with an ice packs. However, grip strength did not show any significant results in male participants ($p > 0.05$). While the grip strength after 30s of cooling was slightly higher (approximate 2%) compared to that before cooling in male and normal-weight groups, there was no statistically remarkable differences ($p > 0.05$).

In addition, in the normal-weight category, a remarkable reduction in grip strength was monitored 15 min after cooling (27.22 ± 9.6 kg) compared to 30s after ice pack application (29.35 ± 8.9 kg, $p < 0.01$). Overall, grip strength was significantly decreased after 15 min compared to that before cooling (28.05 ± 10.4 kg vs. 30.17 ± 9.9 kg; $p < 0.01$) (Table 2). In addition, grip strength was not significantly different in underweight and overweight groups ($p > 0.05$).

Table 3.**Effects of cooling on grip strength relative to body weight related to gender and BMI classification**

Characteristics of the participants	**Relative grip strength at T0** (Before the experiment) (kg)	**Relative grip strength at T1** (at 30s) (kg)	**Relative grip strength at T2** (at 15min) (kg)	**F**	**p-value**	**Partial Eta Squared** (Effect size)
Gender						
Male (n = 20)	0.64 ± 0.1	0.65 ± 0.1	0.63 ± 0.1	0.90	0.41	0.05
Female (n = 42)	0.49 ± 0.1[b]	0.49 ± 0.1[c]	0.44 ± 0.1	13.51	0.001**	0.25
BMI classification						
Underweight (n = 6)	0.51 ± 0.1	0.53 ± 0.1	0.48 ± 0.1	0.71	0.52	0.12
Normal weight (n = 51)	0.54 ± 0.1[b]	0.54 ± 0.1[c]	0.50 ± 0.1	9.76	0.001**	0.16
Overweight (n = 5)	0.59 ± 0.1	0.56 ± 0.1	0.53 ± 0.1	0.95	0.43	0.19
Total (n = 62)	0.54 ± 0.1[b]	0.54 ± 0.1[c]	0.50 ± 0.1	11.23	0.001**	0.16

Note: One-way repeated measures ANOVA was applied to analyse variances in grip strength between T1, T2 and T3; Bonferroni post-hoc test was applied for multiple comparisons; [a]significant difference between T0 and T1 ($p < 0.01$), [b]significant difference between T0 and T2 ($p < 0.01$), [c]significant difference between T1 and T2 ($p < 0.01$); *$p < 0.05$, **$p < 0.01$.

Discussion

Based on the obtained results, this research showed a significantly reduction in grip muscle strength in female and normal-weight groups after receiving local cooling with an ice pack for 15 min. These results are consistent with previous results of Rabelo et.al. (2016) who used the 10°C ice water immersion method at 3 different times (5, 10, and 30 min). A previous study reported a drop in strength of nearly 20% in absolute values after 15 min of cooling. While Douris et al. (2003) observed the effect of 10°C cold water in whirlpool at 4 different times (i.e., 5, 10, 15, and 20 min) on isometric muscle strength efficiency and it was reported that a period of up to 20 minutes immersion in cold water resulted in a 25% reduction in strength (Douris et al., 2003). They identified significant variations between measurements before and after cooling. Furthermore, previous studies identified an approximately 20–25% decrease in muscle strength after 15–20 min of cooling (Rabelo et al., 2016; Douris et al., 2003). Despite variations in cooling time, method and strength assessment technique, these results corroborate the results of this study. The results of previous studies show that 15 min of cooling can decrease human muscle strength. This can be explained by a decrease in myoelectric activity caused by low tissue temperature, which is the most commonly studied reason for decreased muscle strength due to cooling. This effect may be caused by vasoconstriction moment, which decreases calcium release from sarcoplasmic reticulum. The biochemical reasons for changes in muscle activity caused by cooling have been linked to a reduction in ATP availability and lower affinity of calcium towards myosin, which directly interferes with the formation of cross-bridges required for muscle contraction and results in reducing muscle strength (Douris et al., 2003; Oksa, 2002).

For deeper tissue, local cooling can lower muscle temperature by creating bigger thermal gradients for conductive cooling, which implies that this technique provides a larger heat sink. Local cooling results in reduced or inhibited muscle spindle activity as well as decreased Golgi tendon organ activity, which decreases muscle temperature. Sensory input to the brain indicates that several motor units function compared to those for the ice packs technique (Castle et al., 2006). With a decrease in muscle temperature, a decrease in myosin ATPase activity and calcium storage by sarcoplasmic reticulum is observed. To maintain a certain force and strength at a given temperature, this effect causes the muscle to fire at a lower frequency (Drinkwater, 2008).

The effectiveness of local cooling for physical performance has been extensively researched (Kwon et al., 2013). The general consensus is that local cooling over exercising muscles reduces physical performance due to changes in muscular contractile speed, force generation ability, and neuromuscular properties (Ranatunga, 2018). This is due to the fact that slower Ca++ release from the sarcoplasmic reticulum reduces muscular contraction and relaxation speed, as well as force generation ability in response to lowered muscular temperature (Hurr, 2021). Compared to the results of this study, muscle strength was specified mainly by muscle width; muscle with a greater cross-sectional area produces more strength and can lift more weight than muscle with a slighter cross-sectional area (Dhananjaya et al., 2017). Thus, this observation explains why males are generally stronger than females. In addition, compared to females, males have a high proportion of type II fibres that can produce greater muscle force. Thus, males can exert higher hand grip strength than females (Norman et al., 2011; Tanner et al., 2002). However, our study did not evaluate the muscle girth/width of the participants. Thus, a future study is needed. Compared to the normal-weight group, overweight females had lessened the muscle strength in both upper and lower extremities, which can be expressed by their poor level of daily performances. There was a negative relation between BMI and grip strength in overweight females. Some studies showed that obese female students had remarkably decrease endurance strength than in normal-weight females (Dhananjaya et al., 2017; Podstawski et al., 2013). In female and normal-weight participants, grip strength was found significant loss of muscle strength in 15 min after local cooling application. However, grip strength did not indicate any significant results in male and underweight or overweight participants. A direct positive correlation between body composition and core temperature was discovered, but there was also a controversial relationship between reduced temperature and the ability to generate muscle strength in some literature. Some studies recommended lowering the temperature, while others report no change in strength (Rabelo et al., 2016).

Grip strength is directly related to muscle mass and this is reflected in the differences of strength observed between male and female (Amaral et al., 2019). Males and females have generally different body compositions; females have higher fat mass, and males have higher muscle mass. Males are stronger than females because the male hormone testosterone causes muscle growth. A previous study discovered that testosterone may increase type II fibers, and that males have a high proportion of these fibers. Slightly increased muscle strength in males is also associated with increased bone mineral density, resulting in having greater grip strength than females (Dhananjaya et al., 2017). This biological factor explains, at least in this part, the difference results in grip strength levels and greater reduction in females (Amaral et al., 2019). The factuality that females appear to have a lower percentage of lean tissue results in greater gender difference in upper body strength and the observed effect after cooling. Individuals with normal weight have lower muscle volume than those who are overweight (Drinkwater, 2008).

In individuals with normal weight, a greater effect on muscles by local cooling was observed. Nerve conduction and the sarcomere contraction process can be affected. In females and normal-weight individuals, the peroneal nerve, which innervates muscle with a low muscle volume, is superficial, and its exposure to cold water reduced conductibility (Drinkwater, 2008). Studies have shown that conduction velocity is lowered in terminal nerve endings. Cooling also reduced nerve conduction velocity in motor neuron terminals as well as the number of acetylcholine molecules binding to the postsynaptic receptor which delays the muscle contraction times. Cooling also slows enzyme activity, as well as reducing the rate of force changes (Hurr, 2021).

Our study has some limitations that include absence of controlled skin or muscle temperature, not monitoring menstrual cycle impact in female participants, and unequal number of participants in each group. These limitations might have confounded the results. However, grip strength values in the present study are relative similar to reference values of recent study (Amaral et al., 2019) in both male and female. Our results indicate that grip strength and relative grip strength after 15 min cooling are significantly correlated in female and the normal-weight groups; thus, the impact of ice pack cooling on grip strength depends on the specific characteristics of the participants.

Conclusion

This study purposed to evaluate the influences of local cooling on hand grip strength in healthy young adults depending on gender and BMI classification. The study's uniqueness is that local cooling application was monitored at three different exposure periods among different BMI classifications and the obtained results specified that there was a remarkable decline in handgrip strength among healthy young adults after 15 min of cooling. This phenomenon was observed only in female and in normal-weight groups. However, the obtained results showed that the effects of ice pack cooling on grip strength depended on particular individual's characteristics such as gender and BMI differences. The current study provides exercisers, researchers, physicians, athletes, and coaches with important findings regarding the implementation of local-cooling technique to regulate muscle strength, particular attention should be addressed regarding the baseline characteristics, particular to normal-weight group and female.

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