

ACUTE EFFECTS OF PARTIAL-BODY CRYOTHERAPY ON ISOMETRIC STRENGTH: MAXIMUM HANDGRIP STRENGTH EVALUATION

MASSIMO DE NARDI,¹ LUISA PIZZIGALLI,² ROBERTO BENIS,³ FEDERICA CAFFARO,⁴ AND MARGHERITA MICHELETTI CREMASCO⁴

¹Department of Experimental Medicine, University of Genoa, Genoa, Italy; ²School of Exercise and Sport Sciences, SUIISM, University of Torino, Torino, Italy; ³Department of Biomedical Sciences for Health, University of Milano, Milano, Italy; and ⁴Department of Life Sciences and Systems Biology, University of Torino, Torino, Italy

ABSTRACT

De Nardi, M, Pizzigalli, L, Benis, R, Caffaro, F, and Cremasco, MM. Acute effects of partial-body cryotherapy on isometric strength: maximum handgrip strength evaluation. *J Strength Cond Res* 31(12): 3497–3502, 2017—The aim of the study was to evaluate the influence of a single partial-body cryotherapy (PBC) session on the maximum handgrip strength (JAMAR Hydraulic Hand dynamometer). Two hundred healthy adults were randomized into a PBC group and a control group (50 men and 50 women in each group). After the initial handgrip strength test (T0), the experimental group performed a 150-second session of PBC (temperature range between -130 and -160°C), whereas the control group stayed in a thermo neutral room ($22.0 \pm 0.5^{\circ}\text{C}$). Immediately after, both groups performed another handgrip strength test (T1). Data underlined that both groups showed an increase in handgrip strength values, especially the experimental group (Control: T0 = 39.48 kg, T1 = 40.01 kg; PBC: T0 = 39.61 kg, T1 = 41.34 kg). The analysis also reported a statistical effect related to gender ($F = 491.99$, $P \leq 0.05$), with women showing lower handgrip strength values compared with men (women = 30.43 kg, men = 52.27 kg). Findings provide the first evidence that a single session of PBC leads to the improvement of muscle strength in healthy people. The results of the study imply that PBC could be performed also before a training session or a sport competition, to increase hand isometric strength.

KEY WORDS cryocabin, hand dynamometer, muscle performance, cryostimulation

INTRODUCTION

Muscle contraction is defined by the changes in length of the muscle during contraction: it can be classified into isotonic or isometric. Isometric contraction occurs when the muscle tenses without changing its length. It is required in some sports (for example climbing and gymnastics) and in physical and hand-work activities. Isometric contraction is typical of muscles found in the hands and forearms. Many daily functions and sporting events require high activity levels of the flexor muscles of the forearms and hands. The most common method of assessment of grip strength is the use of a handheld dynamometer. This measurement may provide over all body strength and muscle performance, individual nutritional status and well-being, by a simple and noninvasive evaluation (28). During gripping activities, the muscles of the flexor mechanism in the hand and forearm create grip strength, while the extensors of the forearm stabilize the wrist (31). It is known that temperature is a relevant determinant of muscle performance (19,22). Regarding the cold, it can induce, for example, increased tissue stiffness (27), decreased nerve conduction velocity, and decreased muscle contractility. These effects could reduce athletic performance (11). Isotonic and isometric strength respond differently because of a decrease in temperature (14,18,26). In fact, we know (30) that dynamic activities are more susceptible to the inhibitory effects of cold than isometric contractions. Thus, interestingly, some studies reported that a cold application is an effective way to increase isometric strength (5,18). The human body responds to cold applications with vasoconstriction to maintain the core temperature. After this first response, usually the opposite phenomenon occurs, that is vasodilation, which increases muscle blood flow with increased oxygen supply, therefore potentially improving muscle performance (10).

Cryotherapy is the application of cold agents: It is based on body temperature, diminution through, for instance, immersion into cold water, and application of ice packs or ice vests. Its use is widespread in sports medicine today

Address correspondence to Dr. Massimo De Nardi, massimodenardi@alice.it.
31(12)/3497–3502

Journal of Strength and Conditioning Research
© 2017 National Strength and Conditioning Association



Figure 1. Subject during a cryocabin (Space Cabin, Criomed Ltd, Kherson, Ukraine) session.

and the application of cold has been found to decrease the inflammatory reaction, the pain threshold, swelling, edemas and to reduce the recovery time after both acute and chronic injuries (16,17,29). One of the latest methods in sports medicine and science is whole-body cryotherapy (WBC). Whole-body cryotherapy is based on stimulation with very cold air of the organism of minimally dressed subjects (usually from -110 up to -160°C), either in

a specially designed chamber (WBC) or a cabin (partial-body cryotherapy, [PBC]), for a short period (generally from 150 to 180 seconds), aiming to cause vasoconstriction of the skin vessels (2). The substantial difference between these 2 kinds of cryostimulation treatments is that during a cryocabin session (PBC), the head is not exposed (Figure 1). Whole-body cryotherapy and PBC are repeatedly used in sports practice to hasten the recovery after high-intensity exercises and increase the range of motion (7,9,25). In the past, despite the increasing popularity of WBC and PBC in sports and exercise medicine, a few studies have investigated the effectiveness of these treatments on muscle-performance recovery after exercise in adults (1,7), but to the authors' best knowledge, no study has examined the acute effects of cold dry air exposure on the maximum isometric strength. The hypothesis of this study was therefore that a single PBC session would not significantly worsen the handgrip maximum isometric strength. Considering the small differences in physiological reactions between WBC and PBC short exposure (15), the aim of this study was to test the hypothesis that a single PBC session could influence the maximum handgrip strength as measured by a hydraulic hand dynamometer. There are many categories of handheld dynamometer, and according to the literature (31), the handgrip dynamometer is a method of assessment which can provide the practitioner the most accurate choice, in addition to being an inexpensive tool and easy to use on the field.

METHODS

Experimental Approach to the Problem

There are limited data about the effects of the cryogenic temperatures on isometric strength. Consequently, to evaluate the effects of a single PBC session performed before a maximum handgrip strength test, 100 healthy men and 100 healthy women were required to be present for one time at the testing venue. Both men and women populations were divided into experimental and control groups to assess the differences in maximum isometric

TABLE 1. Sociodemographic information of the participants (mean $\pm$ SD).*

Groups	Age (y)	Height (cm)	Weight (kg)	BMI ($\text{kg}\cdot\text{m}^{-2}$)
Male				
PBC ($n = 50$)	42.42 ± 14.17	178.02 ± 7.1	79.41 ± 9.52	25.21 ± 3.14
Control ($n = 50$)	37.12 ± 9.32	177.2 ± 5.3	76.12 ± 12.01	24.18 ± 3.61
Female				
PBC ($n = 50$)	41.26 ± 11.73	165.0 ± 5.1	62.0 ± 7.95	22.79 ± 2.79
Control ($n = 50$)	39.56 ± 11.38	167.12 ± 6.2	64.94 ± 7.79	23.38 ± 3.03

*PBC = partial-body cryotherapy; BMI = body mass index.

TABLE 2. Descriptive statistics of handgrip strength values (kg) at T0 and T1 in each group of participants.*

Sex	Groups	T0	T1
Women	Control (<i>n</i> = 50)		
		Mean	31.15
		SD	5.43
		SEM	0.77
	PBC (<i>n</i> = 50)		
		Mean	28.47
		SD	4.45
		SEM	0.63
	Total sample (<i>n</i> = 100)		
		Mean	29.81
Men	Control (<i>n</i> = 50)		
		Mean	47.81
		SD	6.74
		SEM	0.95
	PBC (<i>n</i> = 50)		
		Mean	50.75
		SD	8.77
		SEM	1.24
	Total sample (<i>n</i> = 100)		
		Mean	49.28
Women + Men	Control (<i>n</i> = 100)		
		Mean	39.48
		SD	10.35
	PBC (<i>n</i> = 100)		
		Mean	39.61
		SD	13.16
	Total sample (<i>n</i> = 200)		
		Mean	39.55
		SD	11.81

*PBC = partial-body cryotherapy.

before testing commenced to avoid influencing the recorded variable. In addition, participants were required not to undertake exercise for 24 hours before the laboratory trial. They were also instructed not to take medications or supplements during the study. One hundred men and 100 women were enrolled in the study, approved by the National Medical Ethics Committee, and signed a written informed consent. The research was undertaken in compliance with the Helsinki Declaration. Subjects were then randomly divided into a PBC and a control group (50 men aged 26 to 54 years and 50 women aged 26 to 53 in each group). Sociodemographic information for each group is shown in Table 1.

Procedures

On arrival, the participants were made to sit for 30 minutes wearing only swimwear, socks, and wooden clogs to acclimate to the room temperature ($22.0 \pm 0.5^\circ \text{C}$). After acclimation, each participant performed the maximal handgrip strength test of the dominant hand (17) using a portable JAMAR Hydraulic Hand dynamometer (Sammons Preston Rolyan Nottinghamshire, United Kingdom) as recommended for use in healthy people (3,4). It was regulated for each subject: fitting the hand and allowing flexion at the metacarpophalangeal joints. When the individual adjustment operations were completed, each subject performed 3 submaximal voluntary isometric contractions maintained for 5 seconds as familiarization to the testing protocol. The scale of the dynamometer indicated handgrip strength in kilograms (kg).

Our experiment was conducted in May and June. The testing protocol consisted of 3 maximal voluntary isometric contractions maintained

for 5 seconds with rest period of at least 60 seconds; the highest value was used for the determination of the maximal grip strength. The procedure and the methodology used during the handgrip strength test were performed according to the standards (20,21,24). Specific verbal instructions were given to subjects before the evaluations and the experiments were performed with verbal encouragement (23).

Subjects

All volunteers were adults and underwent an initial physical examination by the qualified physician; all participants with epicondylitis, chronic shoulder pain, episodes of fractured wrist, and disabilities in their upper extremities, and contraindications to PBC were excluded from the study. Subjects were all recreational athletes and were not accustomed to partial body treatments. To minimize the effects of circadian variation, the timing of measurements were consistent between trials. Subjects were also instructed to refrain from consuming alcohol, caffeine, theine, or hot drinks 24 hours

The PBC group, after the baseline handgrip strength measurement (T0 PBC), completed one treatment in a cryocabin (Space Cabin; Criomed Ltd., Kherson, Ukraine), an open tank equipped with a mobile lift which allows to adjust the height of every subject, so the guest is exposed to the very cold dry air up to the shoulders, with the neck and the head out of the cabin. This device can accommodate only one subject for each session (Figure 1). The 150 seconds duration and set temperature range between -130 and -160°C were used as recommended for cryocabin sessions (13). During the

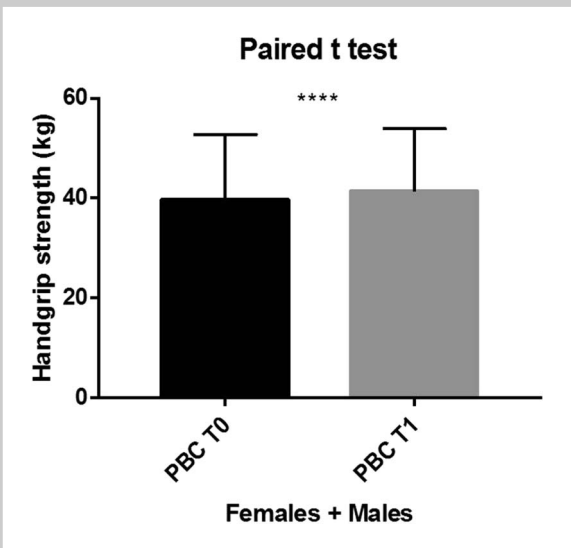


Figure 2. T test partial-body cryotherapy (PBC) male group before cryotherapy (PBC T0) versus PBC male group after cryotherapy session (PBC T1) $p < 0.007$.

session, subjects wore swimwear, a pair of gloves, woolen socks, and wooden clogs. Participants were instructed to turn around continuously (standing rotations) in the cabin for the 150-second session. The control group, after the baseline measurement (T0 Control), was instructed to perform the same movements (standing rotations) for the same duration (150

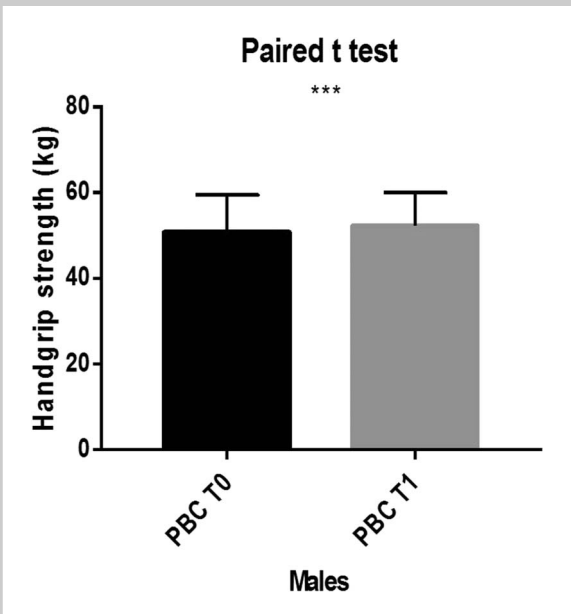


Figure 3. T test partial-body cryotherapy (PBC) female group before cryotherapy (PBC T0) versus PBC female group after cryotherapy session (PBC T1) $p < 0.0001$.

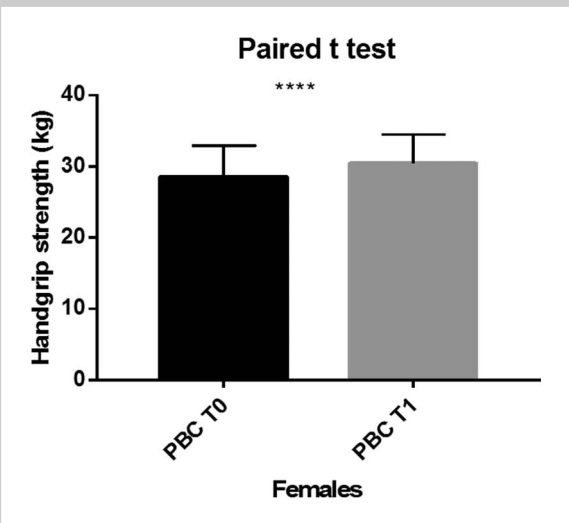


Figure 4. T test partial-body cryotherapy (PBC) female and male groups before cryotherapy (Control T0) versus PBC female and male groups after cryotherapy session (Control T1) $p < 0.007$.

seconds) in the turned off cryocabin ($22.0 \pm 0.5^{\circ}\text{C}$). After the cryocabin treatment (T1 PBC) or control duty (T1 Control), the maximal handgrip strength test was repeated.

Statistical Analyses

The SPSS for windows (SPSS 22.0, Inc., Chicago, IL) was used for statistical analyses. Data are presented as mean $\pm$ *SD*.

A series of independent *t*-tests was used to evaluate any possible differences in the anthropometric characteristics and differences among handgrip strength values both in female and male PBC and control groups.

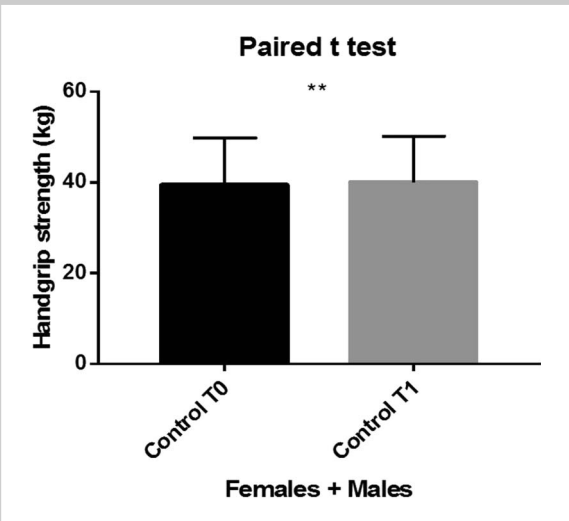


Figure 5. T test partial-body cryotherapy (PBC) female and male groups before cryotherapy (PBC T0) versus PBC female and male groups after cryotherapy session (PBC T1) $p < 0.0001$.

A mixed-design repeated measures analysis of variance (ANOVA) was used to analyze handgrip strength values. Time (T0, T1) was the within-subjects factor, whereas group (PBC and control) and sex were the between-subjects factors. For all analyses, statistical significance was set at $\alpha = 0.05$.

Partial eta-square (η^2) effect sizes were determined and interpreted using the following criteria: 0.01 = small; 0.06 = medium; and 0.13 = large.

RESULTS

Age, weight, height, and body mass index were not significantly different between PBC and control groups at baseline ($p > 0.05$) both in male and in female groups. Descriptive statistics regarding the handgrip strength values in all groups of participants are shown in Table 2. Whereas control group increased handgrip strength (mean values) from T0 to T1 around 0.5 kg in both genders, PBC group showed an increase of around 1.5 kg in men (Figure 2) and around 2 kg in women (Figure 3).

A high intraclass correlation emerged (ICC 0.987), (95% confidence interval 0.975–0.992). The results of the ANOVA showed a significant main effect of exercise (continuously standing rotations) in both groups ($F_{1,196} = 45.59$, $p \leq 0.05$, $\eta^2 = 0.189$) on handgrip strength increase and a significant Exercise $\times$ Group interaction ($F_{1,196} = 12.77$, $p \leq 0.05$, $\eta^2 = 0.061$). Both PBC and control groups showed an increase in handgrip strength values compared with T0 (T0 = 39.55 kg, T1 = 40.68 kg), especially in the experimental group (Control: T0 = 39.48 kg, T1 = 40.01 kg; PBC: T0 = 39.61 kg, T1 = 41.34 kg) (Figures 4–5). The analysis also reported a significant effect of Gender ($F_{1,196} = 491.99$, $p \leq 0.05$, $\eta^2 = 0.715$), with female participants showing lower handgrip strength values compared with male participants (females = 30.43 kg, males = 52.27 kg).

DISCUSSION

The aim of this study was to test the hypothesis that a single PBC session would not significantly worsen the handgrip maximum isometric strength as measured by a hydraulic hand dynamometer in a large population of healthy men and women. We found an increase, compared with baseline, in the maximum handgrip strength after a short time period (150 seconds) both in the control group and in PBC group. Our results confirmed that immediately after a PBC session, there was a more remarkable increase in handgrip strength compared with baseline and to the control group. Although further investigation is warranted, from a practical perspective, the use of PBC may be important for individuals who practice activities where isometric strength is required (e.g., climbing and racket sports).

The results reported in this study are in line with others that evaluated the effect of cold agents on the maximal isometric force (5,18,30). In fact, a 10-minute cold bath provided an increase of the maximum isometric force produc-

tion of the hip extensor significantly greater than that of the control and hot bath (water at 43° C) groups (5). Furthermore, Burke et al. found a gender difference in the cold group, with men experiencing greater increases. Additionally, a previous study verified that after placing ice on the arm for 15 minutes, muscle force increased significantly and, in line with our findings, even in the control group, there was a minimal increase in strength compared with baseline (18). Also, Vieira et al. (30) reported that 20 minutes of ice-pack application increased isometric peak torque of plantar flexors ($p < 0.001$) in healthy men.

The muscle temperature immediately after a PBC session is not known, but it is known (13) that skin temperature of the forearm is near to 23° C. Only one study, to the authors' best knowledge, evaluated the muscle temperature after a WBC session: Costello et al. (8) measured vastus lateralis temperature and recorded significantly lower temperatures ($p \leq 0.05$) only after 20, 30, 40, 50, and 60 minutes after WBC. No significant differences ($p > 0.05$) were found immediately and 10 minutes after the cryogenic exposure. Therefore, it has been documented that a reduction on muscle temperature below the threshold of 27° C could decrease the maximal isometric force level (6). Hence, it would make sense, according to Westerlund (32), to assume that a single cold dry air exposure in PBC does not lead to reach the threshold of 27° C for the muscle temperature immediately after the session, under which a decrease of the maximal isometric force level occurs. To confirm this, immediately after a PBC exposure we noticed an increase in the maximal hand grip strength, that may be induced by the vasodilation occurred after the PBC session, which determines an increased blood flow to muscles and, according to Nodehi Moghadami and Dehghane (18), this may have a beneficial effect on muscle function. At the same time, other authors (12,30) suggested that the increase in isometric strength after cold exposures could depend on a compensatory mechanism that fosters the recruitment of higher threshold motor units in response to the inhibition caused by cooling, considering that this mechanism is prominent in isometric contractions because of lower dependence on this activity in relation to tissue stiffness caused by cooling.

PRACTICAL APPLICATIONS

The results of this study provide the first evidence that a single session of PBC can have a significant and positive impact on isometric strength in healthy people. This is of practical value for coaches and practitioners aiming to include this treatment to improve isometric strength. Again, our results represent a new approach to the longstanding problem of the PBC protocols standardization. In fact, in light of what has emerged, it is now clear that coaches can schedule PBC sessions also before a training session or a competition, for example, climbing, racket sports, and gymnastics ring performances, where hand isometric strength is required.

ACKNOWLEDGMENTS

The authors thank all participants involved in this study. No external financial support received. The results of this study were not endorsed by the National Strength and Conditioning Association.

REFERENCES

1. Akehi, K, Long, BC, Warren, AJ, and Goad, CL. Ankle joint angle and lower leg musculotendinous unit responses to cryotherapy. *J Strength Cond Res*, 2016; doi: 10.1519/JSC.0000000000001357.
2. Banfi, G, Lombardi, G, Colombini, A, and Melegati, G. Whole-body cryotherapy in athletes. *Sports Med* 40: 509–517, 2010.
3. Beaton, DE, O'Driscoll, SW, and Richards, RR. Grip strength testing using the BTE work simulator and the Jamar dynamometer: A comparative study. *J Hand Surg* 20A: 293–298, 1995.
4. Bohannon, RW, Peolsson, A, Massy-Westropp, N, Desrosiers, J, and Bear-Lehman, J. Reference values for adult grip strength measured with a Jamar dynamometer: A descriptive meta-analysis. *Physiotherapy* 9: 11–15, 2006.
5. Burke, DG, MacNeil, SA, Holt, LE, MacKinnon, NC, and Rasmussen, RL. The effect of hot or cold water immersion on isometric strength training. *J Strength Cond Res* 14: 21–25, 2000.
6. Clarke, DH and Royce, J. Rate of muscle tension development and release under extreme temperatures. *Int Z Angew Physiol Einschl Arbeitsphysiol* 19: 330–336, 1962.
7. Costello, JT, Baker, PR, Minett, GM, Bieuzen, F, Stewart, IB, and Bleakley, C. Whole-body cryotherapy (extreme cold air exposure) for preventing and treating muscle soreness after exercise in adults. *Cochrane Database Syst Rev* 9: CD010789, 2015.
8. Costello, JT, Culligan, K, Selfe, J, and Donnelly, AE. Muscle, skin and core temperature after -110°C cold air and 8°C water treatment. *PLoS One* 7: e48190, 2012.
9. De Nardi, M, La Torre, A, Benis, R, Sarabon, N, and Fonda, B. Acute effects of whole-body cryotherapy on sit-and-reach amplitude in women and men. *Cryobiology* 71: 511–513, 2015.
10. De Ruiter, CJ, Jones, DA, Sargeant, AJ, and de Haan, A. Temperature effect on the rates of isometric force development and relaxation in the fresh and fatigued human adductor pollicis muscle. *Exp Physiol* 84: 1137–1150, 1999.
11. Dixon, PG, Kraemer, WJ, Volek, JS, Howard, RL, Gomez, AL, Comstock, BA, Dunn-Lewis, C, Fragala, MS, Hooper, DR, Hakkinen, K, and Maresh, CM. The impact of cold-water immersion on power production in the vertical jump and the benefits of active dynamic exercise warm-up. *J Strength Cond Res* 24: 3313–3317, 2010.
12. Drinkwater, E. Effects of peripheral cooling on characteristics of local muscle. *Med Sport Sci* 53: 74–88, 2008.
13. Fonda, B, De Nardi, M, and Sarabon, N. Effects of whole-body cryotherapy duration on thermal and cardio-vascular response. *J Therm Biol* 42: 52–55, 2014.
14. Howard, RL Jr, Kraemer, WJ, Stanley, DC, Armstrong, LE, and Maresh, CM. The effects of cold immersion on muscle strength. *J Strength Cond Res* 8: 129–133, 1994.
15. Louis, J, Schaal, K, Bieuzen, F, Le Meur, Y, Filliard, JR, Volondati, M, Brisswalter, J, and Hausswirth, C. Head exposure to cold during whole-body cryostimulation: Influence on thermal response and autonomic modulation. *PLoS One* 10: e0124776, 2015.
16. Mac Auley, DC. Ice therapy: How good is the evidence? *Int J Sports Med* 22: 379–384, 2001.
17. Meeusen, R and Lievens, P. The use of cryotherapy in sports injuries. *Sports Med* 3: 398–414, 1986.
18. Nodehi Moghadami, A and Dehghane, N. The effects of local heating and cooling of arm on maximal isometric force generated by the elbow flexor musculature in male subjects. *IRJ* 10: 62–65, 2012.
19. Oksa, J, Rintamaki, H, and Rissanen, S. Muscle performance and electromyogram activity of the lower leg muscles with different levels of cold exposure. *Eur J Physiol Occup Physiol* 75: 484–490, 1997.
20. Peolsson, A, Hedlund, R, and Oberg, B. Intra- and inter-tester reliability and reference values for hand strength. *J Rehab Med* 33: 36–41, 2001.
21. Pizzigalli, L, Micheletti Cremasco, M, La Torre, A, Rainoldi, A, and Benis, R. Hand grip strength and anthropometric characteristics in Italian female national basketball teams. *J Sports Med Phys Fit*, 2016 [Epub ahead of print].
22. Ranatunga, KW. Force and power generating mechanism(s) in active muscle as revealed from temperature perturbation studies. *J Physiol* 588(Pt 19): 3657–3670, 2010.
23. Richards, LG. Posture effects on grip strength. *Arch Phys Med Rehabil* 78: 1154–1156, 1997.
24. Richards, LG, Olson, B, and Palmiter, P. How forearm position affects grip strength. *Am J Occup Ther* 50: 133–138, 1996.
25. Russell, M; Birch, J, Love, T, Cook, CJ, Bracken, RM, Taylor, T, Swift, E, Cockburn, E, Finn, C, Cunningham, D, Wilson, L, and Kilduff, LP. The effects of a single whole body cryotherapy exposure on physiological, performance and perceptual responses of professional academy soccer players following repeated sprint exercise. *J Strength Cond Res*, 2016. published Ahead-of-Print. doi: 10.1519/JSC.0000000000001505.
26. Sargeant, AJ. Effect of muscle temperature on leg extension force and short-term power output in humans. *Eur J Appl Physiol* 56: 693–698, 1987.
27. Sekihara, C, Izumizaki, M, Yasuda, T, Nakajima, T, Atsumi, T, and Homma, I. Effect of cooling on thixotropic position-sense error in human biceps muscle. *Muscle Nerve* 35: 781–787, 2007.
28. Shea, J. The Importance of Grip Strength. 2007.
29. Swenson, C, Sward, L, and Karlsson, J. Cryotherapy in sports medicine. *Scand J Med Sci Sports* 6: 193–200, 1996.
30. Vieira, A, Oliveira, AB, Costa, JR, Herrera, E, and Salvini, TF. Cold modalities with different thermodynamic properties have similar effects on muscular performance and activation. *Int J Sports Med* 34: 873–880, 2013.
31. Waldo, B. Grip strength testing. *Nat Strength Cond Ass J*: 32–35, 1996.
32. Westerlund, T. *Thermal, Circulatory, and Neuromuscular Responses to Whole-Body Cryotherapy*. Oulu, Finland: Universitatis Ouluensis, 2009.