http://dx.doi.org/10.5392/IJoC.2012.8.2.097

Effects of Different Cool-down Exercise Methods on Muscle Strength and Endurance of the Lower Extremities

ChangHwan Bae
Department of physical therapy
Daegu University, Kyungsan, 712-714, South Korea

SungHyoun Cho
Department of physical therapy
Daegu University, Kyungsan, 712-714, South Korea

Gak HwangBo
Department of physical therapy
Daegu University, Kyungsan, 712-714, South Korea

ABSTRACT

The purpose of this study was to investigate the effects of various cool-down exercises on muscular strength and endurance. After receiving a treadmill training for main exercise, the subjects conducted isotonic and isometric cool-down exercises four times for three weeks. Isotonic exercise with leg press of 10kg was repeated by 20 times and isometric exercise was conducted at flexion of hip joint and knee joint with leg press of 10kg by maintaining it for 6 sec and resting for 2 sec by 20 times. Muscular strength after exercise was measured with 1 RM by times and muscular endurance with maximum repetition frequency using time to keep for loading the weight of 10 RM and 65% of maximum muscular strength. As a result of comparing and analyzing measured values, exercise recovery shape of isotonic and isometric cool-down group were more effective than rest recovery shape of the control group. The isometric cool-down group was more effective than isotonic cool-down group. In conclusion, isometric exercise was more effective than isotonic exercise or simple rest on muscular strength and endurance.

Keywords*: Cool-down exercise, Isometric, Isotonic, Strength, Endurance.*

1. INTRODUCTION

Growing interest in health in the modern society has led to increased attention to exercise aimed at enhancing physical strength and improving health. To enhance physical strength and maintain health, appropriate and regular exercise is more important than anything else [1]. However, those who enjoy exercise mostly skip cool-down exercise and the next day a lot of them feel fatigue [2].

Muscle strength refers to the force generated from a maximum voluntary contraction [3] and is one of the important elements to evaluate physical strength level [4]. The one repetition maximum (RM) is first measured to evaluate muscle strength. Here, the 1RM reflects the total amount of weight that can be lifted only once through a full range of motion [5]. The 1RM test is mainly used because it enables determining the intensity of muscle exercise in exercise prescriptions [6]. Muscle endurance means capabilities to repetitively perform muscle contraction against resistance for a long time [7].

Muscle contractions to develop muscle functions can be divided into isotonic contraction and isometric contraction. Isometric contraction is to make muscle contraction and exert strength without joint movement and it is also called static contraction, which functionally stabilizes joints [8]. Exercise should be performed by selecting the load on the angle with the weakest muscle strength in the whole range of motion. This method is disadvantageous in that contraction of such angle is made at a maximum level but maximum contraction at other joint angles is not exerted [9]. On the other hand, isotonic contraction refers to muscle contraction where muscle length shortens and muscle load is constant from the start to the end of amplitude [8]. Muscle contraction against fixed resistance results in tension close to maximum tension and enhancement of muscle strength around at joint angles at which exercise is performed [9].

Among studies that compared rest and exercise recovery,

* *Corresponding author, Email: hbgak @daegu.ac.kr*
Manuscript received Apr. 30, 2012; revised Jun 17, 2012; accepted Jun 19, 2012

McMaster et al. [10]'s study reported that exercise recovery resulted in more swift recovery than rest recovery and Lee [11] said that exercise recovery was more effective than rest recovery in recovering blood lactate. Based on such previous studies, a lot of research has been performed on stretching, jogging, and walking as cool-down exercises. Nonetheless, research on the effects of cool-down exercise after main exercise in accordance with the forms of muscle contraction is still lacking. Accordingly, this study aimed to examine the effects of different cool-down exercise methods on muscle strength and endurance by isotonic and isometric cool-down exercise of the lower extremities using a leg press to its subjects.

2. SUBJECTS AND METHODS

2.1 Subjects

This study was conducted in February 2012 on 30 students in an exercise therapy room. After receiving a treadmill training for main exercise, the subjects conducted isotonic and isometric cool-down exercises four times for three weeks. Muscle strength and endurance were measured with a leg press prior to the experiment and for three weeks after the experiment. Sufficient explanation was made to the subjects on the purpose, methods, precautions of this experiment, and written consent to voluntarily participate in this experiment was obtained from them. The subjects were equally and randomly assigned to the control group (no cool-down exercise), the experimental group I (isotonic cool-down exercise) and the experimental group II (isometric cool-down exercise). The subjects did not take any medication during the experiment. The criteria for inclusion of the subjects in this experiment were: no use of their legs for their job; no open wounds or inflammatory diseases; no performance of excessive exercise at least three months before the experiment in order to take into consideration muscle fatigue. The general characteristics of subjects were shown in Table 1.

Table 1. General characteristics of subjects (Mean±SD).

	Control group (n=10)	Experimental group I (n=10)	Experimental group II (n=10)	p
Gender	man : 4 woman : 6	man : 5 woman : 5	man : 6 woman : 4	.885
Age (yrs)	21.60±2.32	22.10±1.97	21.60±1.96	.827
Height (cm)	167.53±7.91	168.58±9.51	169.22±7.61	.902
Body weight (kg)	60.83±10.38	62.44±10.67	61.34±9.65	.938
BMI[1)] (Kg/m^2)	21.51±1.78	21.80±1.74	21.32±2.16	.853

1. BMI: Body mass index

2.2 Methods

2.2.1 Study Tools

A scale (TANIA-HD-310, Japan) and an extensometer (ZENITH-D5-102, Korea) were used to measure the subjects' weights and heights, respectively. For the main exercise, a treadmill was used. For the measurement of muscle strength and endurance of the lower extremities, a dynamometer (JLW instruments Inc, CS200 Dynamometer, USA), a leg press (Multileg Donghwa, Korea), and 5, 10kg bio-dumbbells (Samsung, Korea) were used. A stopwatch (S123-4000, SEIKO, Japan) was used to measure exercise time.

2.2.2 Study process

Maximum muscle strength and endurance of all the subjects were measured in order to examine 1RM and 10RM of each of them. As warm-up exercise, the subject performed stretching exercise for five to ten minutes, main exercise on the treadmill for 15 minutes, followed by cool-down exercise. Isotonic and isometric cool-down exercise presented by Kim et al. [5]'s study was revised and complemented into the cool-down exercise method of the present study. The subject of the isotonic exercise sat on the leg press and contracted flexor and extensor muscles of the hip joint and the knee joint for two second each time for a total of 20 times by pushing a 20 kg weight. The subject of the isometric exercise sat on the leg press and maintained a 10Kg weight while slightly flexing the hip joint and the knee joint for six seconds and then took a rest for two seconds; this exercise was also repeated twenty times. After the cool-down exercise and a two-minute rest, muscle strength and endurance were measured. 1RM was measured using the leg press and muscle strength was quantified using the dynamometer [12].

The muscle strength of the quadriceps femoris muscle of the right lower extremity was measured using a dynamometer. The subject pressed his/her head and back against a backrest and bent his/her knee joints to 60° during the measurement. A support was placed under the subject's knee joints, the subjects ankles were placed at the neutral position and firmly fixed to the extent that the ankles could not be moved and the muscle strength was measured when the quadriceps femoris muscle was in the state of maximum isometric contraction. The muscle strength was measured three times and the average value of the results of the measurement was calculated and determined as the maximum isometric contraction. Between each measurement, the subject was given one minute for a rest to prevent muscle fatigue [13].

After muscle strength was measured, the knee joint was extended to a maximum level in order to examine changes in muscle endurance; the time to maintain 10RM weight and the maximum number of repetitions using 65% of muscle strength were measured. The subjects regularly participated in the exercise program four times per week for three weeks. This study compared measurement values prior to the experiment and for three weeks after the experiment in order to look at effects of cool-down exercise on the recovery of muscle strength and endurance of the lower extremities [14].

2.2.3 Statistical methods

SPSS/PC 12.0 for Windows (ICC, Chicago, USA) was

employed for statistical data analysis. Means and standard deviations of the subjects' physical characteristics and of the data measured by each variable were calculated. A paired t-test was conducted in order to compare before and after the experimental results in each group and an one-way analysis of variance (one-way ANOVA) was performed to compare change rates between the groups. Tukey's test was used as a post-hoc test between the groups after the exercise. Statistical significance was set at $p < .05$ for all the analyses.

3. RESULTS

In order to figure out the effects of post-workout isotonic and isometric cool-down on leg muscular strength and endurance, comparative analysis of muscular strength and endurance between experimental group I and II and control group was carried out using dynamometer and leg press with 30 college students as the subject. The results of the study are as follows.

3.1 Comparison of muscular strength among groups before and after the experiment

Average value of dynamometer of the control group went down after the cool-down exercise. There was a statistically significant increase of dynamometer average value in the experimental group I and II ($p<.05$). And through post hoc analysis among the experimental groups, it was found that the dynamometer values of the experimental group I and II increased compared with the control group ($p<.05$) (Table 2). 1RM average of the control group decreased after the exercise. 1RM average of the experimental group II significantly increased after the exercise ($p<.05$). And post hoc analysis showed that 1RM of the experimental group I and II increased after the experiment in comparison to the control group ($p<.05$) (Table 3). One way analysis of variance was done to verify statistical significance of the three groups, and there was significant difference in dynamometer value among the groups after the experiment ($p<.05$) (Table 6).

Table 2. Change of dynamometer on each group (unit: kg).

	Pre	After 3 weeks	t	p
CG	87.70±10.64	80.56±10.47	3.164	.067
EG I	70.28±14.38	72.85±12.83*	-2.162	.030
EG II	68.63±11.28	72.31±11.20*	-1.649	.006

Tested by Tukey' HSD multiple rage test, each group significantly differences compared with the control group (*: $p < .05$)
CG : Control group
EG I : Experimental group I (Isotonic cool-down exercise)
EG II : Experimental group II (Isometric cool-down exercise)

Table 3. Change of 1RM on each group(unit: kg).

	Pre	After 3 weeks	t	p
CG	63.87±10.99	57.72±9.02	3.592	.139
EG I	60.72±11.47	62.59±9.05*	-1.673	.065
EG II	59.63±13.52	61.48±11.62*	-1.178	.003

Tested by Tukey' HSD multiple rage test, each group significantly differences compared with the control group (*: $p < .05$)

3.2 Comparison of muscular endurance among groups before and after the experiment

Average repeat count of 65% maximum muscular strength of the control group before exercise showed a significant decrease after the exercise ($p<.05$). After cooling down exercise, average repeat count of 65% maximum muscular strength of the experimental group I and II before exercise significantly increased ($p<.05$) (Table 4). And through post hoc analysis among groups, it was observed that repeat count of 65% maximum muscular strength of group I and II increased compared with the control group ($p<.05$). Average 10RM holding time of the control group decreased after the exercise. Average 10RM holding time of the experimental group II significantly increased after the cool-down. Post hoc analysis among the experimental groups showed that showed that 10RM holding time of the group I and II increased compared with the control group ($p<.05$) (Table 5). One way analysis of variance was done to verify statistical significance of the three groups, and there was significant difference in repeat count of 65% maximum muscular strength and 10RM holding time among the groups ($p<.05$) (Table 6).

Table 4. Change of average repeat count of 65% maximum muscular strength on each group (unit: count).

	Pre	After 3 weeks	t	p
CG	20.78±4.77	18.63±3.92	3.612	.026
EG I	16.94±3.32	19.53±2.42*	-2.244	.003
EG II	16.68±2.91	20.55±2.31*	-9.093	.000

Tested by Tukey' HSD multiple rage test, each group significantly differences compared with the control group (*: $p < .05$)

Table 5. Change of 10RM holding time on each group (unit: kg).

	Pre	After 3 weeks	t	p
CG	84.45±10.52	76.38±9.08	2.690	.341
EG I	89.03±8.28	90.05±6.19*	-.845	.210
EG II	90.57±13.08	91.49±10.77*	.424	.012

Tested by Tukey' HSD multiple rage test, each group significantly differences compared with the control group (*: $p < .05$)

Table 6. Comparison of muscular strength and endurance in each group.

			SS	MS	F	p
DM[1)]	Pre	Bet[4)]	2232.81	1116.41	7.491	.221
		Wi[5)]	4023.94	149.04		
	Post	Bet	425.99	213.00	1.598	.003**
		Wi	3598.09	133.26		

1RM	Pre	Bet	96.96	48.48	.334	.719
		Wi	3917.54	145.09		
	Post	Bet	130.29	65.14	.655	.527
		Wi	2684.66	99.43		
65%[2)]	Pre	Bet	105.41	52.71	3.738	.366
		Wi	380.68	14.10		
	Post	Bet	18.46	9.23	1.043	.037*
		Wi	238.85	8.85		
Hold[3)]	Pre	Bet	202.68	101.34	.868	.431
		Wi	3152.59	116.76		
	Post	Bet	1390.85	695.42	8.814	.001**
		Wi	2130.25	78.90		

SS: Sum of square, MS: Mean square
1. DM: Dynamometer, 2. 65%: average repeat count of 65% maximum muscular strength, 3. HOLD: 10RM holding time,
4. Bet: Between, 5: Wi: Within
*: p<.05, **: p<.01

4. DISCUSSION

Modern people make efforts to increase muscle strength and endurance through diverse exercises in order to improve their health and a variety of relevant studies have been conducted [12], [15], [16].

Kim [17] reported that weight training was effective in increasing explosive strength, muscle strength, and muscle endurance but such effects varied according to different weights and the number of repetitions. Exercise was effective only when a new overload stimulus was given once the body had adapted to the given overload [18].

Fatigue inducing substances such as lactic acid, lactate dehydrogenase (LDH), and creatine phosphokinase (CPK) that have important effects on fatigue after exercise are indicators for analysis of physiological motor skills and fatigue patterns based on energy metabolic processes [19]. These substances are used as standards for enhancing athletes' performance, determining the degree of excessive training and adjusting exercise intensity [20], and utilized as grounds for analyzing lactic acid thresholds and recovery patterns that are regarded as important indicators for the evaluation of cardiopulmonary functions during incremental exercise [21]. Decreased muscle pain and endurance after exercise are associated with increased LDH and CPK levels in the blood, which indicates the degree of muscle damage [22].

Accumulation of lactic acid in the muscles leads to muscle fatigue, which is a state of failure to maintain required muscle strength [23]. Muscle fatigue associated with accumulation of lactic acid in the muscles and blood is acidification resulting from changes in hydrogen ion concentration and decreased pH levels in the muscle cells, and major known etiologies of muscle fatigue are: decreased efficiency in muscle contraction; inhibition of binding of calcium ion and troponin within the groove between actin filaments; inhibition of calcium ion release from the sarcoplasmic reticulum; interference with activities of enzymes such as fructose phosphate enzyme resulting from muscle cell acidification; disruption with the system of neural stimulus delivery; reduction in utilization of free fatty acid; inhibition of glucose regeneration; and metabolic disturbances of the electronic transport system [24]. Such muscle fatigue leads to decreased muscle function and susceptability to injuries, making it impossible to sustain exercise [25].

Male students with no regular exercise experiences were divided into two groups. One group received short distance interval training and the other group received plyometrics and both groups saw their muscle strength and endurance of the lower extremities significantly increase [26]. Improved muscle strength and endurance indicate muscle recovery. Recovery is divided into rest recovery and exercise recovery, which is superior to exercise recovery.

Warm-up exercise is crucial in order to relieve circulatory system responses triggered by exercise, restore heart rates and blood pressure to stable levels, reduce the possibility of post-exercise hypotension and vertigo by maintaining adequate venous return [15]. A cool-down exercise is necessary in two terms: removal of lactic acid accumulated in the skeletal muscle and temperature adjustment [27]. A cool-down exercises include main exercise with less intensity, walking, jogging, stretching exercise, and recreation games [28].

In a study that looked at effects of different post-exercise recovery patterns on lactic acid concentration, Kim [17] reported that exercise recovery resulted in more significant lactic acid recovery rates than rest recovery as time passed after exercise. Walking exercise, one of dynamic cool-down exercises, recovered muscle fatigue fast relative to stretching exercise, one of static cool-down exercises [29]. In the present study, as in previous studies, isotonic and isometric cool-down exercises in the form of dynamic recovery were applied and the result was that muscle strength and endurance recovered effectively and isometric cool-down exercise was more effective than isotonic cool-down exercise.

Kim et al. [5]' study noted that the reason why isometric cool-down exercise recovered dynamic muscle strength faster than isotonic cool-down exercise was because recovery of phasic muscle fibers took longer than that of tonic muscle fibers and therefore maximal voluntary contraction following isotonic exercise occurred slower than after isometric exercise. However, in previous research, isometric exercise times twice as much as isotonic exercise time was applied and there was no interval resting time [30]. In the present study, resting time was included, and rest recovery effect was controlled and therefore more precise exercise recovery was expected.

The experimental group I and II conducted one set of cool-down exercise four times per week for three weeks and their results were compared with that of the control group. The experimental groups I and II with dynamic recovery patterns recovered muscle strength and endurance of the lower extremities more significantly than the control group. In particular, the experimental group II which conducted isometric cool-down exercise had better recovery results than the experimental group I. The results showed that cool-down exercise was effective in increasing muscle strength and endurance. However, this study has limitations of a short

experimental period of three weeks and a small number of study subjects and therefore it is difficult to generalize its results. Diverse studies on a larger number of subjects according to age or gender with more objective and precise measurement methods are considered to provide more detailed explanations on effects of cool-down exercise.

5. CONCLUSION

In this study, experimental groups conducted isotonic and isometric cool-down exercise following warm-up exercise and main exercise and their results were compared with that of the control group. The experimental groups I and II saw their muscle strength and endurance significantly increase relative to the control group. The experimental group II which conducted isometric cool-down exercise obtained better recovery results than the experimental group I. Given the above results, exercise for dynamic recovery, in particular, isometric cool-down exercise, is considered effective in recovering muscle strength and endurance. General therapeutic exercise programs mainly consist of warm-up, main training and cool-down exercises and most ordinary persons finish exercises without performing cool-down exercises. Cool-down exercises can remove the lactic acid accumulated in skeletal muscles to relieve muscle fatigue and increase muscle strength and muscle endurance. As future studies, muscle fatigue, muscle strength and muscle endurance should be studied more through stretching, isometric, isotonic and isokinetic cool-down exercises after resistance exercises as main exercises to develop specialized exercise programs to be diversely grafted on athletes and ordinary persons.

REFERENCES

[1] E. J. Park, H. J. Ku, and J. G. Lee, "Setting of proper recovery exercise intensity to recover from lactate fatigue," *Journal of Korean Physical Education Association for Women*, vol.18, no.1, 2004, pp. 67-75.

[2] G.-Y. Kim, *The effect of warm up and rest method blood lactate concentration*, Master´s thesis, Dongguk University, 1991.

[3] Y. S. Ji, and J. C. Lee, *Mechanisms of clinical exercise prescription*, History of Education the 21st century, Seoul, 2010.

[4] U. S. Kim, Y. S. Jin, and T. W. Kim, *Exercise therapy III*, The History of Academic Date, Seoul, 1991.

[5] M. J. Kim, S. N. Shin, E. K. Im, and C. H. Yi, "Effect of recovery on dynamic strength after isotonic or isometric cool-down exercise," *Korean Academy of University Trained Physical Therapists*, vol.1, no.1, 1994, pp. 67-74.

[6] Y. S, Kwon, S. L. Lee, J. M. Hwang, and S. K. Lim. "The study on regression analysis of one repetition maximal strength from a 7-10 repetition submaximal strength test in twenties females," *Korean Society of Sports Medicine*, vol.20, no.1, 2002, pp 65-71.

[7] W. E. Prentice, M. I. Voight, *Techniques in musculoskeletal rehabilitation*, Williams & Wilkins, Baltimore, 1999.

[8] L. K. Smith, E. L. Weiss, and L. D. Lehmknhl, *Brunnstrom's clinical kinesiology*, 5th ed., Philadelphia, 1990.

[9] S. Y. Park, H. H. Choi, and C. B. Park. "A study of comparison on the isometric and isokinetic muscular strength in collegiate students," *The Journal of physical Education*, vol.27, 1999, pp 273-286.

[10] W. C. McMaster, T. Stoddard, and W. Duncan, "Enhancements of blood lactate clearance following maximal swimming," *American Journal Sports Medicine*, vol.17, no.4, 1989, pp472-7.

[11] S.-W. Lee, *The effect of recovery using the different resting mode in baseball pitching*, Master' thesis, Seoul University, Seoul, 2001.

[12] H. W. Mitchell, H. R. Peter, M. O. Robert, and L. E. Armstrong, *ACSM's guidelines for exercise testing and prescription*, 6th ed., Philadelphia, 2006.

[13] R. J. Ploeg, H. J. Oosterhuis, and J. Reuvekamp, Measuring muscle strength, *Journal of Neurology*, vol.231, no.4, 1984, pp200-3.

[14] S. H. Lee, "The effects of speed interval training and plyometric training on leg strength and endurance," *Korean Sports Research*, vol.16, no.3, 2005, pp 487-493.

[15] I. Smilios, T. Pilianidis, M. Karamouzis, and S. P. Tokmakidis, "Hormonal responses after various resistance exercise protocols," Medicine and Science in Sports and Exercise, vol.35, no.4, 2003, pp 644-654.

[16] T.-H. Lim, Effect of warm-up exercise intensity on energy metabolism during submaximal exercise, Master's thesis, Sejong University, Seoul, 2006.

[17] J.-H. Kim, *Effect of muscular resistance training intensity and whey protein, β-Carotene combined supplementation on muscular function, immune function and antioxidant enzyme Activity*, Unpublished doctoral dissertation, Keimyung University, Daegu, 2008.

[18] W. J. Lee, J. H. Kim, and G. B. Park, *Personal training for the beautiful body*, Daekyung books, Seoul, 2011.

[19] H. S. Gang, G. J. Kim, T. U. Kim, H. M. Kim, G. T. Jang, and J. G. Jeon, *Physiology of sport and exercise*, 4th ed., Daehan Media, Seoul, 2011.

[20] H. Itoh, T. Yamazaki, Y. Shimode, T. Wakyama, A. Tamura, S. Yamamoto, Y. Sato, and M. Miyamura, "Vitamin E supplementation attenuates leakage of enzymes following 6 successive days of running training," *International Journal of Sports Medicine*, vol. 21, no.5, 2000, pp 369-374.

[21] M. L. Buono, T. R. Clancy, and J. R. Cook, "Blood lactate and ammonium ion accumulation during graded exercise in humans," *Journal of Applied Physiology*, vol. 57, no.1, 1984, pp 135-139.

[22] S. W. Cha, S. G. Shin, and I. S. Lim. "The effect of passive recovery, massage, cold & hot bath and aroma therapy on fatigue metabolic substrate after 10km running," *Korean Academy Society of Exercise Nutrition*, vol.1, no.1, 2006, pp 37-42.

[23] R. H, T. Edwards, Human muscle function and fatigue: Physiological Mechanisms, Ciba Foundation Symposium

no.82, pp 1-18. London, Pitman Medical.
[24] G. J. Kim, and S. G. Jo, "*Blood lactate concentration and performance*," The sports science institute thesis, Korea University, vol.27, no.3, 1989, pp 71-82.
[25] J. H. Lee, "The effects of spiral balance taping(SBT) on experimental strength decrement index and strength decrement index," *Korea Sport Research*, vol.16, no.5, 2005, pp 339-346.
[26] S. H. Lee, "The effects of speed interval training and plyometric training on leg strength and endurance," *Korean Sports Research*, vol.16, no.3, 2005, pp 487-493.
[27] E. L. Fox, and D. K. Mathews, *The physiological basis of physical education and athletics*. 3rd ed., Saunders College Publishing, Philadelphia, 1981.
[28] S. G. Hwang, *Exercise physiology*, Daehan Books, Seoul, 1988.
[29] B.-H. Kim, *The influence that the type of cooling down has on the recovery of muscle fatigue after resistance training*, Master`s thesis, Chungang University, Seoul, 2006.
[30] A. F. Morris, D. H. Clarke, and A. Danis, "Time to maximal voluntary isometric contraction(MVC) five different muscle groups in college adults," *Research Quarterly for Exercise and Sports*, vol.54, no.2, 1983, pp 163-168.

Chang-Hwan, Bae
He received the degree of M.S. degree in the sports management in 2010 from Ulsan university, Korea. And now he is being doctorate degree in physical therapy, Daegu university, Korea. His main research interests include biomechanics and sports physical therapy.

Sung-Hyoun, Cho
He received the degree of M.S. degree in the physical therapy in 2010 from Daegu university, Korea. And now he is being doctorate degree in physical therapy, Daegu university, Korea. His main research interests include biomechanics and therapeutic exercise.

Gak, HwangBo
He received the degree of B.S., M.S. and Ph.D. in the department of physical therapy from Daegu university, Korea in 1993, 1996, 2003 years respectively. His main research interests include biomechanics and hippotherapy.