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The effect of warm-ups with stretching on the isokinetic moments of collegiate men

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Performing warm-ups increases muscle temperature and blood flow, which contributes to improved exercise performance and reduced risk of injuries to muscles and tendons. Stretching increases the range of motion of the joints and is effective for the maintenance and enhancement of exercise performance and flexibility, as well as for injury prevention. However, stretching as a warm-up activity may temporarily decrease muscle strength, muscle power, and exercise performance. This study aimed to clarify the effect of stretching during warm-ups on muscle strength, muscle power, and muscle endurance in a nonathletic population. The subjects of this study consisted of 13 physically active male collegiate students with no medical conditions. A self-assessment questionnaire regarding how well the subjects felt about their physical abilities was administered to measure psychological readiness before and after the warm-up. Subjects performed a non–warm-up, warm-up, or warm-up regimen with stretching prior to the assessment of the isokinetic moments of knee joints. After the measurements, the respective variables were analyzed using nonparametric tests. First, no statistically significant intergroup differences were found in the flexor and extensor peak torques of the knee joints at 60°/sec, which were assessed to measure muscle strength. Second, no statistically significant intergroup differences were found in the flexor and extensor peak torques of the knee joints at 180°/sec, which were assessed to measure muscle power. Third, the total work of the knee joints at 240°/sec, intended to measure muscle endurance, was highest in the aerobic-stretch-warm-ups (ASW) group, but no statistically significant differences were found among the groups. Finally, the psychological readiness for physical activity according to the type of warm-up was significantly higher in ASW. Simple stretching during warm-ups appears to have no effect on variables of exercise physiology in nonathletes who participate in routine recreational sport activities. However, they seem to have a meaningful effect on exercise performance by affording psychological stability, preparation, and confidence in exercise performance.

Keywords: Stretching, Warm-up, Exercise performance

INTRODUCTION

Warm-ups, which increase blood flow into the involved muscles and elevate muscular temperature, are performed for 5 to 15 min before engaging in the main exercise. Performing warm-ups can lower the risk of injuries in the muscles and tendons, as well as reduce heavy loads on the heart, which can occur when high-intensity exercises are suddenly started (Powers et al., 2013). Passive/active warm-ups increase adenosine triphosphate turnover, which reinforces muscular functions, muscle cross-bridge cycling rate, and oxygen uptake kinetics, which significantly affects exercise performance (McGowan et al., 2015). They are also composed of light gymnastics, low-intensity forms of main exercises, and/or stretching.

Stretching is most commonly performed to increase the range of motion (ROM) of joints and is effective for the maintenance

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and enhancement of exercise performance and flexibility, as well as for injury prevention (American College of Sports Medicine, 2014; Bandy et al., 1998; Nakamura et al., 2014; Sim et al., 2015). However, recent studies have reported that pre-exercise stretching may temporarily decrease muscle strength, muscle power, and exercise performance (Cramer et al., 2004). Despite these findings, it has been widely applied in current sports settings because professional athletes who participate in competitive sports, including amateur sports club members, firmly believe that warm-ups are a prerequisite to achieve the best athletic performance (McGowan et al., 2015).

Hence, in this study, to clarify the effects of routine pre-exercise stretching on muscular functions, nonathlete subjects were grouped into pre-exercise non–warm-up, aerobic warm-up, and aerobic warm-up with stretching groups. Isokinetic equipment was used to assess muscle strength, muscle power, and muscle endurance of the knee joints.

MATERIALS AND METHODS

The subjects of this study included 13 students from Sahmyook University in Seoul, Republic of Korea. All subjects had no medical problems and consented to participate in the experiment after the purpose of the study was fully explained to them. Their physical characteristics are as shown in Table 1. This study was approved by the ethics committee of the Institutional Review Board of Sahmyook University.

To achieve the purpose of this study, the subjects were asked to avoid drinking alcohol and smoking 1 week before the experiment, not to participate in excessive physical activity or non-routine social activities, and to maintain normal sleeping hours to ensure proper test data was obtained. On the day of the experiment, they were asked to consume a light meal, arrive at the laboratory by 09:00 a.m., and rest.

To compare muscle strength and power according to the presence or absence of warm-ups with stretching, the subjects were classified into a control group consisting of those who did not perform warm-ups (NWU), an aerobic warm-up group (AWU) consisting of those who performed simple running and joint exercises, and an aerobic warm-up with stretching group (aerobic-stretch-warm-ups, ASW). NWU directly underwent isokinetic muscle testing without warm-ups, while AWU started power walking at an strength of 40%–60% of predicted maximum heart rate, performed light running for 10 min, and then underwent isokinetic muscle testing. ASW performed light running for 10 min, performed static stretching, and then underwent isokinetic muscle testing.

Table 1. Characteristics of the male subjects (n = 13)

Characteristic	Mean ± SD
Age (yr)	22.38 ± 2.29
Height (cm)	172.62 ± 6.81
Weight (kg)	68.65 ± 13.80
Percent fat (%)	12.51 ± 6.90

SD, standard deviation.

The stretching program consisted of straddling, seated calf stretching, and standing quadriceps stretching for the lower body. Two repetitions of each stretching motion were performed for 20 sec each and the entire stretching program took 5 min to perform. All subjects rested for 1 min after warming up and then underwent isokinetic muscle testing of the knee joints. The sequence of performance of each warm-up exercise was individually randomized. In the successive weeks, each group was tested according to the type of warm-up performed. The testing was conducted for 3 weeks, and all groups were allowed a week to rest in between tests.

A knee extension/flexion isokinetic dynamometer (Humac Norm Testing & Rehabilitation System, CSMI, Stoughton, MA. USA) was used for this study. First, the subjects were asked to have a seat on the machine stand, which was designed to allow the hip joint to bend 90°. Then, the anatomical axis of the rotation of the knee joint was adjusted in accordance with the dynamometer axis of the dynamical system. The upper body, pelvis, and femoral region were fixed using a 3-point safety belt and thigh strap, and the axis of the foot and dynamometer was fixed to the direct upper part of the medial ankle bone by using a Velcro strap. The opposite lower extremity was fixed with a limb stabilization bar. To prevent the influence of the body weight of the axis of motion of the tested lower leg and isokinetic machine on the torque of the knee joint, the gravity effect torque was measured and entered into a computer with the ROM limited to between 0° extension and 90° flexion. Then, the test procedure was explained to the subjects. They were asked to extend and flex the knee by exerting their maximum strength as fast as possible while keeping their trunk up against the back rest during the test and to hold onto the handles. The subjects performed the maximal test of four repetitions. Each maximal test was conducted with an angular speed of 60°/sec to measure isokinetic muscle strength and an angular speed of 180°/sec to measure isokinetic muscle power. In addition, the muscle endurance test was conducted with an angular speed of 240°/sec. The exercise was conducted twice prior to testing to familiarize the subjects with the test, thereby achieving optimal results. Moreover, to provide motivation during the testing of maximal isokinetic strength, power, and endurance, the subjects were verbally encouraged and allowed to view their torque graphs during testing as a form of visual feedback.

Subjects' self-assessed physical condition was also measured in order to understand the psychological readiness of exercise according to the type of warm-up. NWU measured the subjective assessment of their own physical condition before and after resting and then examined isokinetic muscular function tests. AWU and ASW also measured the participants' subjective assessment of their physical state before and after warm-ups. The physical condition self-assessment used a 5-point Likert scale (1, very bad; 2, bad; 3, average; 4, good; 5, very good).

To analyze muscle strength, power and endurance, measurements of the left and right knee joints were divided into each independent variable before data processing was performed. Statistical analysis was conducted with IBM SPSS ver. 18.0 (IBM Co., Armonk, NY, USA). All data are reported as mean ± standard deviation (SD). This study investigated the differences among three types of warm-ups in 13 male subjects, as well as changes in psychological conditions. Prior to analysis, the Kolmogorov–Smirnov test was used to determine the normality of distribution for the examined variables. Since the data was not normally distributed, a nonparametric test was used to investigate the differences among groups and changes between periods. Based on the results of the Kolmogorov–Smirnov test, the nonparametric Kruskal–Wallis rank test were used to examine the differences of variables among groups and the Wilcoxon test was used to investigate psychological conditions before and after warm-ups within times in each group. Next, the Mann–Whitney *post hoc* test was implemented if there were significant differences in the Kruskal–Wallis test. The significance of all data was established at $P \leq 0.05$.

RESULTS

In this study, prior to the evaluation of muscle strength (60°/sec), muscle power (180°/sec), and muscle endurance (240°/sec) of the knee joints, warm-ups and warm-ups with stretching were performed. The results are presented in Tables 2-4.

The comparative analyses revealed no significant differences among NWU, AWU, and ASW, respectively, as follows: 96.23 ± 26.47 vs. 95.73 ± 27.02 vs. 94.88 ± 24.52 for flexor peak torque

Table 2. Comparative results of isokinetic moments at 60°/sec in three types' warm-ups

Isokietic moment	Upper legs' part	Warm-ups types			Kruskal–Wallis test	
		NWU	AWU	ASW	χ^2	*P*-value
Peak torque at 60°/sec	Flexor	96.23 ± 26.47	95.73 ± 27.02	94.88 ± 24.52	0.007	0.996
	Extensor	183.5 ± 39.94	176.81 ± 42.62	177.35 ± 40.01	0.307	0.858

Values are presented as mean ± standard deviation.
NWU, non–warm-ups; AWU, aerobic-warm-ups; ASW, aerobic-stretch-warm-ups.

Table 3. Comparative results of isokinetic moments at 180°/sec in three types' warm-ups

Isokietic moment	Upper legs' part	Warm-ups types			Kruskal–Wallis test	
		NWU	AWU	ASW	χ^2	*P*-value
Average power at 180°/sec	Flexor	75.62 ± 20.29	79.04 ± 20.72	78.27 ± 18.59	0.427	0.808
	Extensor	127.31 ± 28.82	127.85 ± 30.71	130.62 ± 29.36	0.335	0.846

Values are presented as mean ± standard deviation.
NWU, non–warm-ups; AWU, aerobic-warm-ups; ASW, aerobic-stretch-warm-ups.

Table 4. Comparative results of isokinetic moments at 240°/sec in three types' warm-ups

Isokietic moment	Upper legs' part	Warm-ups types			Kruskal–Wallis test	
		NWU	AWU	ASW	χ^2	*P*-value
Total work at 240°/sec	Flexor	1,165.00 ± 352.97	1,185.85 ± 300.98	1,214.12 ± 354.31	0.237	0.888
	Extensor	1,957.85 ± 494.75	1,931.00 ± 472.60	2,006.08 ± 475.51	0.564	0.754

Values are presented as mean ± standard deviation.
NWU, non–warm-ups; AWU, aerobic-warm-ups; ASW, aerobic-stretch-warm-ups.

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Table 5. Differences and changes of physical conditioning in three types' warm-ups

Warm-ups type	Prevalue	Postvalue	Wilcoxon-test	
			Z	*P*-value
NWU	3.08±1.04	3.00±1.15	-0.086	0.931
AWU	2.62±1.04	3.00±0.71	-1.508	0.132
ASW	3.08±0.76	3.77±0.60	-3.000	0.003
Kruskal–Wallis test				
χ^2	1.826	6.360		
P-value	0.401	0.042		
Mann-Whitney *post hoc*	-	AWU<ASW		

Values are presented as mean±standard deviation.

(χ^2=0.007, P=0.996) and 183.50±39.94 vs. 176.81±42.46 vs. 177.35±40.01 for extensor peak torque (χ^2=0.307, P=0.858) at an angular speed of 60°/sec; 75.62±20.29 vs. 79.04±20.72 vs. 78.27±18.59 for flexor average power (χ^2=0.427, P=0.808) and 127.31±28.82 vs. 127.85±30.71 vs. 130.62±29.36 for extensor average power (χ^2=0.335, P=0.846) at an angular speed of 180°/sec; 1,165.00±352.97 vs. 1,185.85±300.98 vs. 1,214.12±354.31 for flexor total work (χ^2=0.237, P=0.888) and 1,957.85±494.75 vs. 1,931.00±472.60 vs. 2,006.08±475.51 for extensor total work (χ^2=0.564, P= 0.754) at an angular speed of 240°/sec.

The results of the subjective self-assessment of physical condition are shown in Table 5. The scores of the subjective self-assessment of physical condition before warm-up in NWU, AWU, ASW are 3.08±1.04, 2.62±1.03, 3.08±0.76 each. Before warming up, there were no statistical differences in the subjective self-assessment of physical condition among the groups. Scores on the subjective assessment of physical conditioning for AWU after aerobic warm-ups was 3.00±0.71. Although the score was higher than before performing aerobic warm-ups, it was not a significant difference (Z=-1.508, P=0.132). Scores on the subjective assessment of physical conditioning for ASW after aerobic warm-ups and stretching was 3.77±0.60, which was significantly higher than before (Z=-3.000, P=0.003).

DISCUSSION

For warming up, stretching is generally performed following short aerobic exercise, which elevates body temperature, reduces muscle stiffness, and increases elasticity (American College of Sports Medicine, 2014; Gillette et al., 1991; Sapega et al., 1981; Wenos and Konin, 2004). Flexibility exercises are often recommended as an effective way to improve joint ROM and reduce the risk of injury during exercise (Sim et al., 2015). Nevertheless, whether pre-exercise stretching contributes significantly to injury prevention is still unclear. Although stretching improves joint ROM, the effect can become negligible after stretching for 3 minutes (Depino et al., 2000). Some researchers suggest that warm-up stretching decreases exercise performance, including muscle strength and endurance (Fowles et al., 2000; Kokkonen et al., 1998; Nelson et al., 2005). In contrast, McHugh and Cosgrave (2010) argued that if stretching is used as a warm-up activity, it can prevent muscle strains, improve joint ROM, and lead to better athletic performance.

The types of stretching techniques include dynamic stretching, ballistic stretching, static stretching, and proprioceptive neuromuscular facility (PNF). Dynamic stretching is equally effective for sports training and exercise programs. In dynamic stretches, fluid exaggerated movements consist of similar movements to exercise motions (Powers et al., 2013). In contrast, to achieve muscle extension, ballistic stretching uses fast and strong countermovements. As counterstretching poses a potential risk of injury, muscle temperature should be elevated through warm-ups prior to counterstretching. For nonathletes, counter motions may activate stretch reflex and cause injury to muscles and tendons. Static stretching, which is recommended for nonathletes, is greatly effective for enhancing flexibility. This stretching is performed by gradually extending the target muscles to the movement-limiting point and then maintaining the posture for 10 to 30 sec with slight discomfort, followed by 2 to 4 repetitions (Abernethy et al., 1994; Powers and Howley, 2014; Powers et al., 2013). The recommended total duration of stretching by region is 60 sec (American College of Sports Medicine, 2018). PNF stretching is commonly used in rehabilitation programs.

Muscle strength, muscle power, and muscle endurance are important factors for exercise performance. While many scientific studies show that warm-ups improve muscle strength and power during exercise, some recent studies report that warm-ups, including stretching, temporarily reduce muscle strength, explosive strength, and/or sports performance (American College of Sports Medicine, 2018; Garber et al., 2011; McHugh and Cosgrave, 2010). In this context, an investigation into the temporary effects of flexibility exercises on exercise performance is required. In the present study, the subjects were grouped into NWU, AWU, and ASW, and subsequently, muscular functions were assessed. The results of the present study indicate that NWU showed higher rates for both the flexor and extensor at 60°/sec, which is an angular speed for rating muscle strength, although the difference was not statistically significant. At 180°/sec, which is an angular speed for rating muscle power, AWU and ASW exhibited higher rates for the flexor and extensor, respectively, although the difference was not statistically significant. The total work at 240°/sec, which reflects muscle endurance, was higher in ASW for both the flexor and extensor, though not statistically significantly. Accordingly, whether or not stretching was included in warm-ups performed by nonathletes before participating in recreational sports activities, no significant differences were found in regards to exercise performance. Warm-ups appear to provide psychological and physiological preparation for exercise performance. Although warm-ups did not have a statistically significant effect on the variables of physiological aspect, they seem to have a meaningful effect on athletic performance by affording psychological stability, preparation, and confidence for exercise performance.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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