Turkish Journal of Sport and Exercise
http://dergipark.gov.tr/tsed
Year: 2016 - Volume: 18 - Issue: 3 - Pages: 84-91
ISSN: 2147-5652

Static and dynamic stretching have same effects on lower extremity joints kinematics and muscular EMG variability in healthy active males during pedaling

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Abstract

Previous studies about the effect of static and dynamic stretching on forthcoming performance have been reported different results. The purpose of present study was to examine the effects of acute static and dynamic stretching on kinematics and EMG variability of lower extremity joints and Muscles in healthy active males during pedaling. Fifteen physically-active male students voluntarily participated in this research. Lower extremity kinematics and EMG data from six lower extremity muscles were collected during 30 pedaling cycle at 70 RPM in situation where there is no stretching (baseline) and after 2, 5, and 10 min post static and dynamic stretching by MIE motion analysis system. Filtered EMG signals and hip, knee and ankle joints angle and angular velocity were extracted for constructing time series and variability calculation. The results of repeated measures ANOVA showed that there are no significant difference in the variability of Muscular EMG and joints angle and angular velocity at 2, 5, and 10 minutes after static and dynamic stretching ($P > 0.05$). Contrary to previous studies that encouraged coaches and athletes to not use static stretching or to use dynamic stretching instead, the results suggest cyclists can benefits from both stretching types in warm-up programs.

Keywords: Static stretching, Dynamic stretching, EMG variability, Kinematics variability, Pedaling

INTRODUCTION

Warm-up before workout is a common method in professional and recreational athletes. Static stretching (SS) is generally considered as an integral part of sport conditioning programs and pre-exercise warm-up routines. This type of stretching is always practiced in the belief that it assists athletic performance, decreases the risk of injury, and reduces muscle soreness resulting from strenuous activity (18,34,38,39). Nevertheless, some recent studies have concluded that SS has no effect on injury prevention (15,16) or it may temporarily decrease muscle's ability to generate force (3-5,10). This temporary reduction in force generation is referred to stretching-induced force deficit (32), which is considered as a determinant of athletic performance (30). Recent findings encourage athletes to avoid static stretching before sporting events (27) and utilize other forms of stretching (i.e. dynamic stretching (DS)) (37).

Recent researches have suggested that performing DS before exercise can enhance performance without deficit in force production (17,19). Nevertheless, these studies have been very few and have mainly focused on the effect of DS on muscle strength parameters (17) and vertical jump height (19). In addition, studies have demonstrated that most of the effects of stretching on subsequent performance are applied through their impact on post activation, such that SS can reduce it while DS can increase it (13,19,35). Therefore, the time interval between the stretching and subsequent performance plays a vital role in post activation (9), however, researches with different time interval have different results (19,35).

Variability in human movements are changes in motor performance during multiple repetitions of a task. Motor variability was previously considered a noise that indicated an error in design, performance, and output of a movement (22). However, some studies have shown that variability may produce voluntary movements that are highly effective for motor control and coordination (7,8,12). This view is derived from the study of chaotic dynamic of nonlinear systems. According to this view, variability is an essential aspect of the nonlinear dynamics of the neuromotor system. However, the effect of variability on sport skills has received little attention.

Cycling is a well-known athletic and recreational activity with several health benefits. Fleming et al. (14) suggested that stationary cycling at the appropriate cadence and resistance is an effective rehabilitation exercise for patients with anterior cruciate ligament injury to increase muscle activity without subjecting the ligament to undue strain (14). Although cycling is generally regarded as a closed-kinetic chain exercise, the joint position and loading in the kinetic chain may not always be predicted at a particular sequence. Factors such as pedaling rate, body direction, saddle height, and muscle fatigue can affect cycling mechanics (2). So, understanding the variability of lower limb joints kinematics and muscular EMG during pedaling and the effect of stretching on these factors can be useful in developing more effective exercise protocols and decreasing the risk of overuse injuries during cycling. In this research we tried to find if acute static and dynamic stretching as a perturbation (which is use as warm-up protocol) can affect lower limb joints kinematics and muscular EMG variability 2, 5, and 10 minutes post stretching? Our hypothesis was that static and dynamic stretching have different effects on kinematics and muscular EMG variability during pedaling, that is DS reduce and SS increase these parameters. The aim of this study was to examine lower extremity joints kinematics and muscular EMG variability during pedaling after static and dynamic stretching.

MATERIALS & METHODS

Fifteen physically-active male students voluntarily participated in this study (69.02 ± 10.52 kg, 174.00 ± 6.74 cm, and 21.20 ± 1.47 years). The participants had no history of injuries to the head, knee, and ankle or balance disorder and all of them had a right dominant leg. They also completed the Medical Health Questionnaire and signed an informed consent form before taking part in the research. The participants were introduced to static and dynamic stretching protocols, measurements of lower limb kinematics and EMG, and pedaling on bicycle ergometer. The lower extremity kinematics (hip, knee and ankle joints angles and angular velocity) and six lower limb muscles EMG (i.e. soleus, gastrocnemius, tibialis anterior, vastusmedialis, biceps femoris, and rectus femoris muscles) were measured on three sessions with a 48-h interval. Each participant performed general warm- up for 5 min before each session. The first session involved measuring the kinematics and EMG parameters of dominant lower limb while performing 30 pedaling cycle on bicycle ergometer exactly after warm-up. The participants were randomly divided into two groups; one group performs SS while the other group performs DS on second session. The stretching protocol was changed for groups on the third session. During static stretching situation, participants performed SS protocol after warm-up. Immediately after SS, the kinematics and EMG parameters during 30 pedaling cycle were measured. The kinematics and EMG parameters also were measured 2, 5, and 10 min post SS during 30 pedaling cycle, while the participants did not pedal between the times intervals. During dynamic stretching situation, participants performed DS protocol after warm-up. Immediately after DS, the kinematics and EMG parameters during 30 pedaling cycle were measured based on the first session time intervals. Participants did not perform any exercises between session's intervals.

Reflective markers placement and kinematics data collection

To record kinematic data, reflective markers with a diameter of 25 and 19 mm were utilized for hip, knee and ankle joints. These markers were placed on the tuberosity of 5th metatarsal, the lateral malleolus, lateral femoral condyle, the greater trochanter of the femur, and the anterior superior iliac spine. A marker was also placed at the center of the pedal spindle to determine the pedaling cycles. One camera was installed with a 5-m distance from calibration center perpendicular to the sagittal plane of pedaling movement (MIE motion analysis system).The sampling frequency of the camera was set at 100 Hz.

Electrode placement and EMG data collection

Electrodes were placed on soleus (SOL), gastrocnemius (GAS), tibialis anterior (TA), vastusmedialis (VM), biceps femoris (BF), and rectus femoris (RF) muscles that had been reported to be involved in cycling (20). Bipolar Ag/AgCl electrodes with a diameter of 10 mm (Skintact FS-50) were used and SENIAM recommendations were followed for electrode placement. To minimize skin impedance, the skin surface was shaved and cleaned with alcohol. After placing electrodes on the skin, preamplifier cables of the EMG system were connected to the transmitter on the back of the subject. The cables were fixed on the skin in order to minimize artifacts. EMG signals were recorded at the 1000 Hz sampling rate.

After placing the electrodes and reflective markers, participants prepared to perform the pedaling protocol. The participants sat on the bicycle ergometer, and the height of the saddle was adjusted so that when the pedal spindle was at the lowest position, the participant's lower limb would be fully extended. The participants were asked to pedal with an intensity of 70 rate per minute (RPM). Kinematics and EMG data were recorded from lower limbs for 30 s once the intensity reached 70 RPM. During a period of 30 s, the participants pedaled about 36 times, of which 30 consecutive ones were extracted and utilized for variability analysis.

Kinematic data were filtered by the system to remove possible noises. The data related to the angle and angular velocity of the hip, knee and ankle joints were calculated by the device software and used for further investigation. Raw EMG signals were filtered using a second-order dual-pass Butterworth filter with a low cut-off frequency of 10 Hz in order to remove possible artifacts and biological noise and a high-cutoff frequency of 450 Hz. Due to synchronization of the EMG system and the cameras, pedaling cycles were identified using the vertical coordinates of the marker placed at the center of the pedal spindle. Also the beginning and end points of camera and EMG data were specified. After selecting the range, EMG signals were full-wave rectified. Then these signals were linear enveloped and time normalized using the mean EMG data of the 30 cycles. The EMG time series of 30 cycles was used to calculate the variability.

Static and dynamic stretching protocols

Based on the protocols of previous studies (19,36), SS in each limb followed the proximal-to-distal pattern: hip flexors, knee extensors, knee flexors, hip extensors, ankle dorsiflexors, and ankle plantarflexors. Each static stretch was performed by lengthening the muscle to the limit of its range of motion at the pain threshold and was held the position for 30 seconds. There were 2-5 s intervals between stretches to allow for change in body position.

For the DS condition, immediately after the warm-up, each participant assumed a standing upright position and began to perform the DS exercises under the verbal guidance of the experimenter. The exercises were performed in the following order: plantar flexors, dorsiflexors, hip extensors, hamstrings, hip flexors, and quadriceps femoris. Each DS is performed by repetitively bouncing the stretched muscle to its limit of range of motion with 15 repetitions each lasting 2 seconds (19,36). The procedure was performed on the right leg and then the left leg. The same 10- to 15-s rest period was taken between exercises like in the SS protocol.

Variability calculation and mean ensemble curve

First, pedaling cycles were identified using the vertical coordinates of the pedal spindle marker, and 30 cycles were selected and time normalized. By calculating the mean and confidence interval (CI) for the *i*thjoint angle and angular velocity and each muscle EMG, the mean ensemble curve of 30 normalized time series was created.

Equation 1.

$$Y = \frac{\sum_{i=1}^{N} x_i}{N}$$

Equation 2.

$$CI = Y \pm \sqrt{\frac{\sum x_i^2}{N} - Y^2}$$

N is the number of averaged repetitions and x is the actual time series value for the *i*th repetition point. CI was used to create standard deviation graphs around the mean ensemble curve. The distance between two standard deviations indicates variability in the time series. Variability in time series was calculated from the mean ensemble curve and the coefficient of variation (CV).

Equation 3.

$$CV = \frac{\frac{1}{N}\sum_{i=1}^{N} S_i}{\frac{1}{N}\sum_{i=1}^{N} |x_i|}$$

The S is the standard deviation of the mean ensemble curve, x is the ith point on the mean ensemble curve, and N is the total number of points on the curve. CV is the ratio of the standard deviation of the mean ensemble curve to the mean joint angle and angular velocity and muscle EMG. The mean ensemble curves for the Muscular EMG and hip, knee and ankle joints angle and angular velocity during 30 pedaling cycles are shown in Figure 1 to 4 respectively.

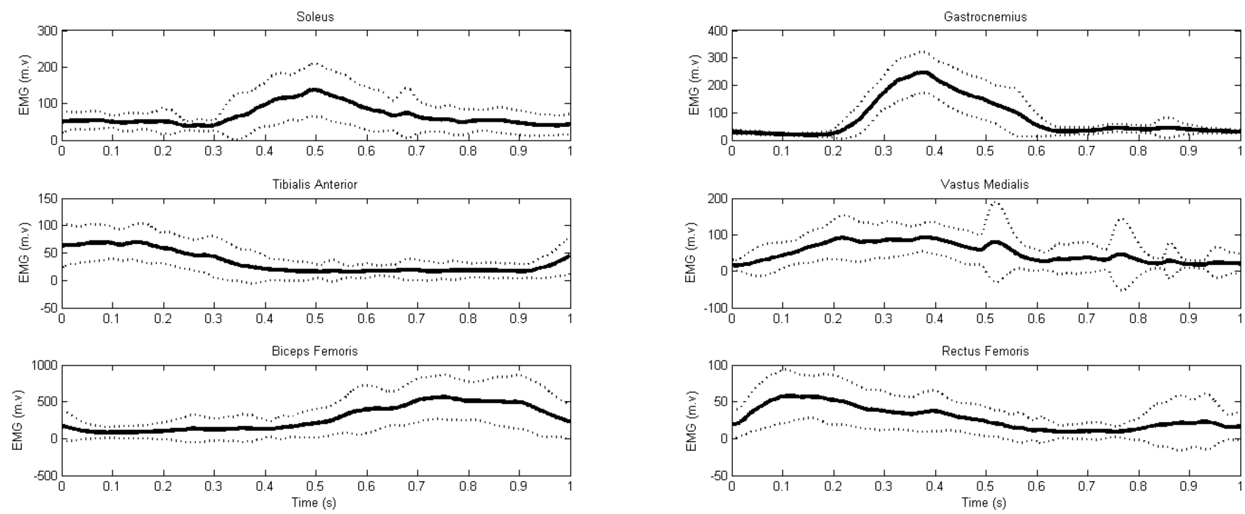

Figure 1. Mean ensemble curves for soleus, gastrocnemius, tibialis anterior, vastusmedialis, biceps femoris, and rectus femoris EMG during 30 pedaling cycle.

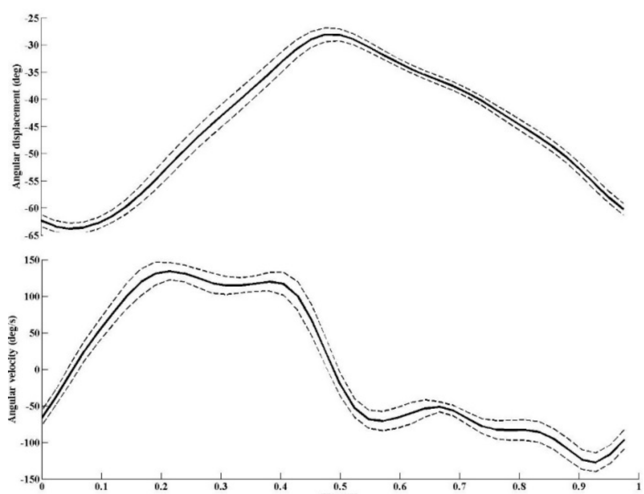

Figure 2. The mean ensemble curves for hip angle and angular velocity during 30 pedaling cycles.

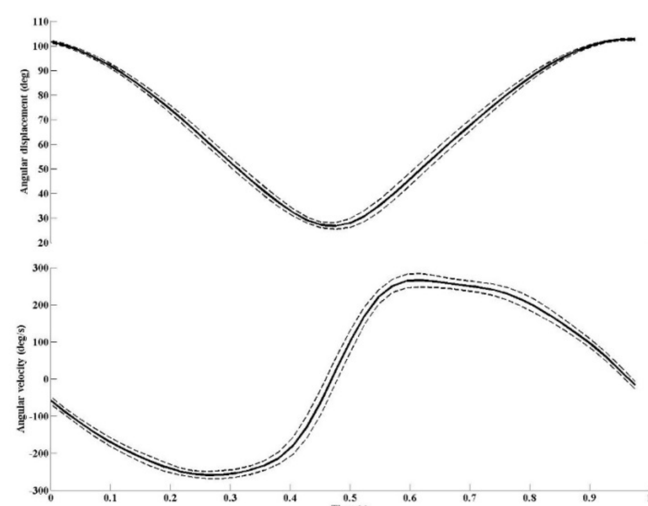

Figure 3. The mean ensemble curves for knee angle and angular velocity during 30 pedaling cycles.

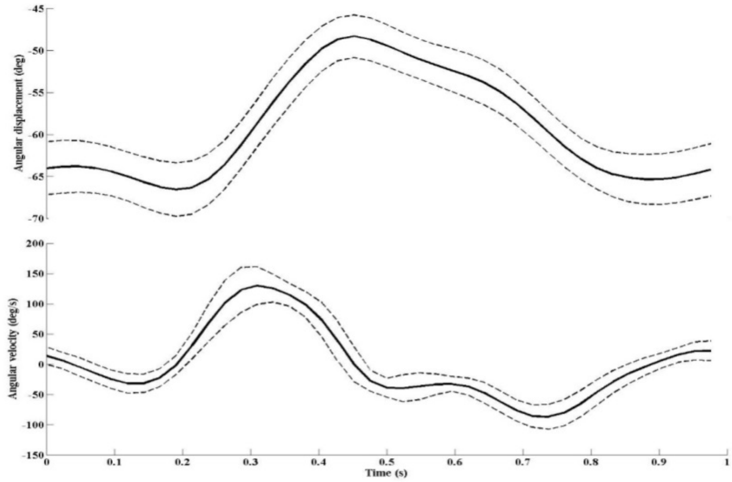

Figure 4. The mean ensemble curves for ankle angle and angular velocity during 30 pedaling cycles.

Table 1. Mean and standard deviation of soleus, gastrocnemius, tibialis anterior, vastusmedialis, biceps femoris, and rectus femoris variability (%) during 2, 5 and 10 min after static and dynamic stretching

Parameter	Muscle	WS	2min+SS	5min+SS	10min+SS	2min+DS	5min+DS	10min+DS	p
C.V	Soleus	0.484±0.195	0.614±0.270	0.622±0.430	0.654±0.435	0.534±0.249	0.528±0.197	0.550±0.235	0.665
	Gastrocnemius	0.507±0.206	0.530±0.188	0.607±0.424	0.576±0.270	0.478±0.179	0.476±0.193	0.465±0.145	0.561
	Tibialisanterior	0.613±0.277	0.911±0.543	0.775±0.343	0.700±0.515	0.787±0.560	0.756±0.363	0.678±0.367	0.663
	Vastusmedialis	0.580±0.275	0.819±0.537	0.868±0.792	0.653±0.508	0.763±0.477	0.574±0.297	0.502±0.186	0.304
	Biceps femoris	0.614±0.142	0.772±0.370	0.780±0.315	0.700±0.247	0.664±0.224	0.746±0.271	0.602±0.163	0.362
	Rectus femoris	0.537±0.179	0.611±0.269	0.723±0.653	0.571±0.214	0.581±0.249	0.617±0.231	0.589±0.243	0.783

WS: Without stretching, SS: Static stretching, DS: Dynamic stretching

Table 2. Mean and standard deviation of joints angle and angular velocity variability (%) during 2, 5 and 10 min after static and dynamic stretching

Parameter	Joint	Angular Parameter	WS	2min+SS	5min+SS	10min+SS	2min+DS	5min+DS	10min+DS	p
C.V	Hip	Angle	2.3±1.6	2.6±0.9	2.6±1.1	2.6±1.0	2.9±1.3	4.6±4.2	2.6±1.0	0.094
		Velocity	13.4±4.9	12.7±2.1	14.2±4.9	13.8±2.9	16.5±6.2	20.0±13.6	16.0±7.0	0.106
	Knee	Angle	3.0±2.3	2.5±0.7	2.8±1.8	2.6±1.0	2.4±0.5	4.0±4.4	2.5±0.8	0.364
		Velocity	8.6±4.9	7.3±1.3	8.0±4.3	7.8±2.5	7.1±1.6	6.9±1.4	7.6±2.5	0.366
	Ankle	Angle	7.6±1.3	6.8±6.6	7.0±3.6	5.4±2.7	5.7±1.6	6.3±1.8	5.9±2.5	0.619
		Velocity	56.1±48.9	53.3±26.2	61.3±38.3	49.0±14.5	41.2±10.5	47.8±16.8	44.3±15.2	0.323

WS: Without stretching, SS: Static stretching, DS: Dynamic stretching

RESULTS

The results of Repeated Measures Analysis of Variance (ANOVA) for muscles EMG and hip, knee and ankle joints angle and angular velocity variability showed that there were no significant difference between these parameters after 2, 5, and 10 minutes of static and dynamic stretching ($p > 0.05$). The mean and standard deviation for the muscles EMG and the hip, knee and ankle joints angle and angular velocity variability after 2, 5, and 10 minutes of static and dynamic stretching are provided in table 1 and table 2 respectively.

DISCUSSION

The purpose of this study was to examine the effect of static and dynamic stretching on muscular EMG and Joints kinematics variability of lower extremity during pedaling in healthy young males. The results showed that the static and dynamic stretching protocols 2, 5, and 10 minutes before pedaling had no significant effect in the variability of soleus, gastrocnemius, tibialis anterior, vastusmedialis, biceps femoris, and rectus femoris muscles activity and also in the variability of hip, knee, and ankle joints kinematics during pedaling.

Previous studies on the effects of static and dynamic stretching on performance have primarily focused on neurophysiological aspects likesstrength and power performance. For example, Hough et al. (19) reported higher and lower vertical jump performance and EMG activity of vastusmedialis at 2 min after static and dynamic stretching respectively (19). The positive effect of dynamic stretching on gait parameters in the elderly has also been reported (29), and it has been demonstrated that dynamic stretching is a more appropriate method for the kinematics of instep soccer kick (1). Nevertheless, the results of studies on the effect of static and dynamic stretching on strength, explosive power, performance, and risk of injury has been equivocal, as studies have reported improvement, decrease, or no change in these variables after static and dynamic stretching (6,16,25,30,34). However, different stretching protocols and durations have been utilized in these studies, making any conclusion about the effect of static and dynamic stretching on subsequent performance more difficult.

Previous studies have attributed the effects of stretching to the neurological and viscoelastic effects of muscles. In neurological effects topic, it has been demonstrated that performing a series of stretches on a resting muscle leads to immediate reduction in strength (stretching-induced force deficit). Reduced range of surface EMG signals during maximal voluntary contractions after stretching suggest that stretch-induced force deficit is a neurological effect (3,4). There is also evidence that stretching-induced force deficit is seen in the un-stretched opposite limb as well. So, there is the possibility that reduced force generation is a neurological effect (11). Some studies that have reported force deficit as a result of stretching have utilized stretching protocols with a duration of less than 4 min (21,27,28,33). Thus, the stretches may not have been enough to reduce passive muscle stiffness. As a result, it is possible that neurological effect occurred rather than viscoelastic effect (reduced passive stretching resistance).

In viscoelasticity effect topic, changes in range of motion and stretching resistance following a bout of acute stretching can be explained utilizing the viscoelastic properties of hysteresis, creep, and stress relaxation. Studies which examined the viscoelastic effects of stretching have revealed that increased range of motion in joints is associated with decrease in passive stretching resistance (23,24,26,32). This reduced stretching resistance can be attributed to reduced muscle stiffness or increased muscle compliance.

In the present research, active male subjects performed the pedaling tasks at a constant load, and the results showed that there is no significant difference in variability of lower extremity muscle activation and joints kinematics 2, 5, and 10 minutes after static and dynamic stretching. The duration of stretching protocols used in this study was about 10 minutes. Static stretches were held until the pain threshold and dynamic stretches were performed with maximum effort. Since the subjects were active, it is possible that the intensity and duration of the stretching protocol were not sufficient to induce significant changes in muscle activation and joints kinematics. However, this study tried to examine the effect of static and dynamic stretching as warm-up and longer duration stretches could not be used. Thus, long-duration stretches may induce significant changes in muscularEMG and joints kinematics parameters during pedaling. However, future research can focus on stretching protocols with different durations and frequencies and with active and sedentary male and female subjects to provide more insights into the effects of static and dynamic stretching on human movements.

The results of the present research suggest that performing static stretches for 30 seconds and dynamic stretches with a frequency of 15 repetitions may not have a significant effect on lower extremity muscle activation and joint kinematics variability during pedaling. Therefore, contrary to previous studies that encouraged athletes to not use static stretching or to use dynamic stretching instead, it is possible that the effect of static and dynamic stretching are not different and athletes and rehabilitating individuals who use pedaling on stationary bicycle as warm-up can benefit from both stretching methods.

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